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F. W. P.

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PROCEEDINGS

OF

THE AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE,

TWENTY-SIXTH MEETING,

HELD AT

NASHVILLE, TENN.,

AUGUST, 1877.

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TABLE OF CONTENTS.

PAGE

Officers of the Nashville Meeting vi
Officers of the Sections, Nashville Meeting vii
Local Committee of Nashville Meeting viii
Special Committees of the Association ix
Officers for the St. Louis Meeting xi
Local Committee for St. Louis Meeting xii
Meetings of the Association of American Geologists and Naturalists . . xiii
Meetings of the Association xiv
Act of Incorporation xvi
Constitution of the Association xvii
Order of Proceedings in Organizing a Meeting xxv
Members of the Association:
Patron xxvi
Life Members xxvi
Members xxvi
Fellows xli
Persons elected at Nashville who have not yet accepted membership . . 1
Deceased Members lii

REPORT OF COMMITTEE ON AN INTERNATIONAL GEOLOGICAL EXHIBITION AND CONGRESS 1
REPORT OF THE COMMITTEE ON ZOOLOGICAL NOMENCLATURE TO SECTION D 7
ON INTERNATIONAL SCIENTIFIC SERVICE 57

SECTION A. MATHEMATICS, PHYSICS, AND CHEMISTRY.

Address of E. C. PICKERING, Vice President 63

I. COMMUNICATIONS.

On an alleged error in Laplace's Theory of the Tides. By J. G. BARNARD . 73
On a New Type of Steam Engine, theoretically capable of utilizing the full Mechanical Equivalent of Heat Energy, and on some points in Theory indicating its practicability. By R. H. THURSTON 85
Abstract of Statement of the Extent and Character of the Work of the United States Board Appointed to Test Iron, Steel, and other Metals. By R. H. THURSTON 98
On a New Method of Planning Researches and of Representing to the eye the Results of Combination of three or more Elements in Varying Proportions. By R. H. THURSTON. Illustrated 114
On the Proper Motion of the Trifid Nebula, = M. 20 = G. C. = 4355, etc., R. A. 17h. 53m. 51.8s.; N. P. D. = 113° 1' 39.9" ; 1860.0. By EDWARD S. HOLDEN 120
Improvement in use of Reflecting Goniometer. By HARVEY W. WILEY. Illustrated 123
On the Wave length of the Blue line of the Spectrum of Indium. By T. C. MENDENHALL 125
New Quadruple Objective for Astronomical Telescopes. By E. GUNDLACH. Illustrated 127
Contributions to the Physics of the Gulf of Mexico, and its Chief Affluent, the Mississippi River. By C. G. FORSHEY 134
Physics of the Lower Mississippi River. By C. G. FORSHEY 148
Wind-vane Rotations. By J. W. OSBORNE. Illustrated 174
Titles of Papers read in the Section but not printed 178

II. PERMANENT SUBSECTION OF CHEMISTRY.

The Minerals of a deposit of Antimony Ores in Sevier County, Arkansas. By F. P. DUNNINGTON 181
The action of dilute acid upon Ferrous Sulphide made from cast iron. By F. P. DUNNINGTON 185
The various methods of separating and determining Barium, Strontium and Calcium. By PAUL SCHWEITZER 188
Titles of Papers read in the Subsection but not printed 202

III. SUBSECTION OF MICROSCOPY.

A modification of Wenham's Reflex Illuminator. By R. H. WARD . . 205
Titles of Papers read in the Subsection but not printed 207

SECTION B. NATURAL HISTORY.

Address of O. C. MARSH, Vice President. Illustrated 211

I. COMMUNICATIONS.

Note upon the History and value of the term Hudson River Group in American Geological Nomenclature. By JAMES HALL 259
The Older Rocks of Western North America. By T. STERRY HUNT . . 265
Geology and Topography of the Oil Region of Tennessee, with some account of the Oil Springs and Wells. By J. B. KILLEBREW. Illustrated . . 266
Geology of the Region about the Head-waters of the Androscoggin River, Maine. By J. H. HUNTINGTON. Illustrated 277
On the Annual Deposit of the Missouri River, during the Post Pleiocene. By J. E. TODD 287
On the Classification of the Extinct Fishes of the Lower Types. By E. D. COPE 292
New Specimens from the Water lime Group at Buffalo, N. Y. By A. R. GROTE and W. H. PITT. Illustrated 300
Agamic Reproduction among the Cynipidæ. By H. F. BASSETT . . . 302
On the Respiration of Amia. By B. G. WILDER 306
Titles of Papers read in the Section, but not printed 315

II. PERMANENT SUBSECTION OF ANTHROPOLOGY.

Address of DANIEL WILSON, Chairman 319
Additional Facts concerning Artificial Perforation of the Cranium in Ancient Mounds in Michigan. By HENRY GILLMAN 335
Habits of the Moqui Tribe. By E. A. BARBER 340
The former and Present Number of our Indians. By GARRICK MALLERY . 340
Titles of Papers read in the Subsection but not printed 366

EXECUTIVE PROCEEDINGS.

History of the Nashville Meeting 367
Report of the General Secretary 373
Report of the Permanent Secretary 393
Cash Account of the Permanent Secretary 394
Publication Account of the Permanent Secretary 396

INDEX.

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MEETINGS AND OFFICERS OF THE AMERICAN ASSOCIATION OF GEOLOGISTS AND NATURALISTS.

MEETING.	DATE.	PLACE.	CHAIRMAN.	SECRETARY.	ASSIST. SEC'Y.	TREASURER.
1st	April 2, 1840,	Philadelphia,	Edward Hitchcock,*	L. C. Beck,*		
2d	April 5, 1841,	Philadelphia,	Benjamin Silliman,*	L. C. Beck,*	B. Silliman, jr., C. B. Trego,	
3d	April 25, 1842,	Boston,	S. G. Morton,*	C. T. Jackson,	J. D. Whitney, M. B. Williams,	
4th	April 26, 1843,	Albany,	Henry D. Rogers,*	B. Silliman, jr.,		John Locke.*
5th	May 8, 1844,	Washington,	John Locke,*	B. Silliman, jr., O. P. Hubbard,		Douglas Houghton.*
6th	April 30, 1845,	New Haven,	Wm. B. Rogers,	B. Silliman, jr., J. Lawrence Smith,		Douglas Houghton.*
7th	Sept. 2, 1846,	New York,	C. T. Jackson,*	B. Silliman, jr.,		E. C. Herrick.*
8th	Sept. 20, 1847,	Boston,	Wm. B. Rogers,†	Jeffries Wyman.*		B. Silliman, jr.

*Deceased.

†Professor ROGERS, as chairman of this last meeting, called the first meeting of the new Association to order and presided until it was fully organized by the adoption of a constitution. As he was thus the first presiding officer of the new Association, it was directed at the Hartford meeting that his name be placed at the head of the Past Presidents of the American Association for the Advancement of Science.

MEETING.	DATE.	PLACE.	PRESIDENT.	VICE-PRESIDENT.	GENERAL SECRETARY.	PERMANENT SEC'Y.	TREASURER.
1st	Sept. 20, 1848,	Philadelphia, Pa.,	W. C. Redfield,*		Walter R. Johnson,*		Jeffries Wyman.*
2d	Aug. 11, 1849,	Cambridge, Mass.,	Joseph Henry,*		E. N. Horsford, 1		A. L. Elwyn.
3d	Mar. 12, 1850,	Charleston, S. C.,	A. D. Bache,* 2		L. R. Gibbs, 3		St. J. Ravenel.* 4
4th	Aug. 19, 1850,	New Haven, Conn.,	A. D. Bache,*		E. C. Herrick,*		A. L. Elwyn.
5th	May 5, 1851,	Cincinnati, Ohio,	A. D. Bache,*		W. B. Rogers, 5	S. F. Baird,	S. F. Baird. 6
6th	Aug. 19, 1851,	Albany, N. Y.,	Louis Agassiz,*		W. B. Rogers,	S. F. Baird,	A. L. Elwyn.
7th	July 28, 1853,	Cleveland, Ohio,	Benjamin Pierce,*		S. St. John, 7	S. F. Baird,	A. L. Elwyn.
8th	April 26 1854,	Washington, D.C.,	J. D. Dana,		J. Lawrence Smith,	Joseph Lovering,	J. L. LeConte. 8
9th	Aug. 15, 1855,	Providence, R. I.,	John Torrey,*		Wolcott Gibbs,	Joseph Lovering,	A. L. Elwyn.
10th	Aug. 20, 1856,	Albany, N. Y.,	James Hall,		B. A. Gould,	Joseph Lovering,	A. L. Elwyn.
11th	Aug. 12, 1857,	Montreal, Canada.	Alexis Caswell,* 9	Alexis Caswell,*	John LeConte,	Joseph Lovering,	A. L. Elwyn.
12th	April 28, 1858,	Baltimore, Md.,	Alexis Caswell,* 10	John E. Holbrook,*†	W. M. Gillespie,* 11	Joseph Lovering,	A. L. Elwyn.
13th	Aug. 3, 1859,	Springfield, Mass.,	Stephen Alexander,	Edward Hitchcock,*	William Chauvenet,*	Joseph Lovering,	A. L. Elwyn.
14th	Aug. 1, 1860,	Newport, R. I.,	Isaac Lea,	B. A. Gould,	Joseph LeConte,	Joseph Lovering,	A. L. Elwyn.
15th	Aug. 15, 1866,	Buffalo, N. Y.,	F. A. P. Barnard,	A. A. Gould,* 12	Elias Loomis, 13	Joseph Lovering,	A. L. Elwyn.†
16th	Aug. 21, 1867,	Burlington, Vt.,	J. S. Newberry,	Wolcott Gibbs,	C. S. Lyman,	Joseph Lovering,	A. L. Elwyn.†
17th	Aug. 5, 1868,	Chicago, Ill.,	B. A. Gould,	Charles Whittlesey,	Simon Newcomb, 14	Joseph Lovering,	A. L. Elwyn.†
18th	Aug. 18, 1869,	Salem, Mass.,	J. W. Foster,*	O. N. Rood,	O. C. Marsh,	F. W. Putnam, 15	A. L. Elwyn.†
19th	Aug. 17, 1870,	Troy, N. Y.,	T. S. Hunt, 16	T. S. Hunt,	F. W. Putnam, 17	Joseph Lovering,	A. L. Elwyn.†
20th	Aug. 16, 1871,	Indianapolis, Ind.,	Asa Gray,	G. F. Barker,	F. W. Putnam,	Joseph Lovering,	W. S. Vaux.
21st	Aug. 15, 1872,	Dubuque, Iowa,	J. Lawrence Smith,	Alex. Winchell,	E. S. Morse,	Joseph Lovering,	W. S. Vaux.
22d	Aug. 20, 1873,	Portland, Me.,	Joseph Lovering,	A. H. Worthen.†	C. A. White,	F. W. Putnam,	W. S. Vaux.
23d	Aug. 12, 1874,	Hartford, Conn.,	J. L. LeConte,	C. S. Lyman,	A. C. Hamlin,	F. W. Putnam,	W. S. Vaux.†

1. In place of Jeffries Wyman, *not present.*
2. In place of Joseph Henry, *not present.*
3. In place of E. C. Herrick, *not present.*
4. In place of A. L. Elwyn, *not present.*
5. In place of E. C. Herrick, *not present.*
6. In place of A. L. Elwyn, *not present.*
7. In place of J. D. Dana, *not present.*
8. In place of A. L. Elwyn, *not present.*
9. In place of J. W. Bailey, *deceased.*
10. In place of Jeffries Wyman, *not present.*
11. In place of Wm. Chauvenet, *not present.*
12. In place of R. W. Gibbes, *not present.*
13. In place of W. P. Trowbridge, *not present.*
14. In place of A. P. Rockwell, *called home 1st day.*
15. In place of Joseph Lovering, *in Europe.*
16. In place of Wm. Chauvenet, *too ill to be present.*
17. In place of C. F. Hartt, *in Brazil.*

* Deceased. † Not present at the meeting.

MEETINGS AND OFFICERS OF THE ASSOCIATION (*Continued*).

MEETING.	DATE.	PLACE.	PRESIDENT.	VICE PRESIDENT, SECTION A.
24th	Aug. 11, 1875,	Detroit, Mich.,	J. E. Hilgard,	H. A. Newton,
25th	Aug. 23, 1876,	Buffalo, N. Y.,	William B. Rogers,	Charles A. Young,
26th	Aug. 29, 1877,	Nashville, Tenn.,	Simon Newcomb,	R. H. Thurston,[1]

VICE PRESIDENT, SECTION B.	CHAIRMAN OF PERMANENT SUBSECTION C, CHEMISTRY.	CHAIRMAN OF PERMANENT SUBSECTION D, ANTHROPOLOGY.	CHAIRMAN OF PERMANENT SUBSECTION E, MICROSCOPY.
J. W. Dawson,	S. W. Johnson,	L. H. Morgan,	
Edward S. Morse,	George F. Barker,	L. H. Morgan,	R. H. Ward,
O. C. Marsh,	N. T. Lupton,	Daniel Wilson,*	R. H. Ward,

PERMANENT SECRETARY.	GENERAL SECRETARY.	SECRETARY OF SECTION A.	SECRETARY OF SECTION B.
F. W. Putnam,	S. H. Scudder,	S. P. Langley, T. C. Mendenhall,	E. S. Morse,
F. W. Putnam,	T. C. Mendenhall,	A. W. Wright,	Albert H. Tuttle,
F. W. Putnam,	Aug. R. Grote,	H. C. Bolton,	Wm. H. Dall,

SECRETARY OF PERMANENT SUBSECTION C, CHEMISTRY.	SECRETARY OF PERMANENT SUBSECTION D, ANTHROPOLOGY.	SECRETARY OF PERMANENT SUBSECTION E, MICROSCOPY.	TREASURER.
F. W. Clarke,	F. W. Putnam,	————	W. S. Vaux.
H. C. Bolton,	O. T. Mason,	E. W. Morley,	W. S. Vaux.
P. Schweitzer,	————[2]	T. O. Summers, jr.,	W. S. Vaux.*

[1] In the absence of E. C. Pickering. [2] The Subsection united with Sec. B. * Not present.

COMMONWEALTH OF MASSACHUSETTS.

IN THE YEAR ONE THOUSAND EIGHT HUNDRED AND SEVENTY-FOUR.

AN ACT

To Incorporate the "American Association for the Advancement of Science."

Be it enacted by the Senate and House of Representatives, in General Court assembled, and by the authority of the same, as follows:

Section 1. Joseph Henry of Washington, Benjamin Pierce of Cambridge, James D. Dana of New Haven, James Hall of Albany, Alexis Caswell of Providence, Stephen Alexander of Princeton, Isaac Lea of Philadelphia, F. A. P. Barnard of New York, John S. Newberry of Cleveland, B. A. Gould of Cambridge, T. Sterry Hunt of Boston, Asa Gray of Cambridge, J. Lawrence Smith of Louisville, Joseph Lovering of Cambridge and John LeConte of Philadelphia, their associates, the officers and members of the Association, known as the "American Association for the Advancement of Science," and their successors, are hereby made a corporation by the name of the "American Association for the Advancement of Science," for the purpose of receiving, purchasing, holding and conveying real and personal property, which it now is, or hereafter may be possessed of, with all the powers and privileges, and subject to the restrictions, duties and liabilities set forth in the general laws which now or hereafter may be in force and applicable to such corporations.

Section 2. Said corporation may have and hold by purchase, grant, gift or otherwise, real estate not exceeding one hundred thousand dollars in value, and personal estate of the value of two hundred and fifty thousand dollars.

Section 3. Any two of the corporators above named are hereby authorized to call the first meeting of the said corporation in the month of August next ensuing, by notice thereof "by mail," to each member of the said Association.

Section 4. This act shall take effect upon its passage.

House of Representatives, March 10, 1874.
Passed to be enacted,
John E. Sanford, *Speaker.*

In Senate, March 17, 1874.
Passed to be enacted,
Geo. B. Loring, *President.*

March 19, 1874.
Approved,
W. B. Washburn.

Secretary's Department,
Boston, April 3, 1874.
A true copy, Attest:
David Pulsifer,
Deputy Secretary of the Commonwealth.

CONSTITUTION

OF THE

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Incorporated by Act of the General Court of the Commonwealth of Massachusetts.

Objects.

Article 1. The objects of the Association are, by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of America, to give a stronger and more general impulse and more systematic direction to scientific research, and to procure for the labors of scientific men increased facilities and a wider usefulness.

Members, Fellows, Patrons and Honorary Fellows.

Art. 2. The Association shall consist of Members, Fellows, Patrons and Honorary Fellows.

Art. 3. Any person may become a Member of the Association upon recommendation in writing by two members or fellows, nomination by the Standing Committee, and election by a majority of the members and fellows present in general session.

Art. 4. Fellows shall be nominated by the Standing Committee from such of the members as are professionally engaged in science, or have by their labors aided in advancing science. The election of fellows shall be by ballot and a majority vote of the members and fellows present in general session. But all persons who may be members at the time of the adoption of this constitution may become fellows by signifying their desire to this effect before the first day of August, 1875.

Art. 5. Any person paying to the Association the sum of one thousand dollars shall be classed as a Patron, and shall be entitled to all the privileges of a member and to all its publications.

ART. 6. Honorary Fellows of the Association, to the number of ten for each section, may be elected; the nominations to be made by the Standing Committee and approved by ballot in the respective sections before election by ballot in general session. Honorary Fellows shall be entitled to all the privileges of fellows and shall be exempt from all fees and assessments, and entitled to all publications of the Association issued after the date of their election.

ART. 7. The name of any member or fellow two years in arrears for annual dues shall be erased from the list of the Association, provided that two notices of indebtedness, at an interval of at least three months, shall have been given; and no such person shall be restored until he has paid his arrearages or has been reëlected.

ART. 8. No member or fellow shall take part in the organization or business of both sections at the same meeting.

OFFICERS

ART. 9. The Officers of the Association shall be elected by ballot in general session from the fellows and shall consist of a President, two Vice Presidents, a General Secretary, a Permanent Secretary, a Treasurer, a Secretary of Section A, and a Secretary of Section B; these, with the exception of the Permanent Secretary, shall be elected at each meeting for the following one, and, with the exception of the Treasurer and the Permanent Secretary, shall not be reëligible for the next two meetings. The Permanent Secretary shall be elected at each fifth meeting.

ART. 10. The President, or, in his absence, one of the Vice Presidents, shall preside at all general sessions of the Association and at all meetings of the Standing Committee. It shall also be the duty of the President to give an address at a general session of the Association at the meeting following that over which he presided.

ART. 11. The Vice Presidents shall be the presiding officers of Sections A and B, and of the Sectional Committees, and it shall be part of their duty to give an address, each before his respective section, at such time as the section shall determine. The Vice Presidents may request their respective sections to appoint temporary chairmen to preside over the sessions of the sections, but shall not delegate their other duties.

ART. 12. The General Secretary shall be the Secretary of all general sessions of the Association, and of all sessions of the Standing Committee, and shall keep a record of the business of these sessions. He

shall receive the records from the Secretaries of the Sections, which, after examination, he shall transmit with his own records to the Permanent Secretary within two weeks after the adjournment of the meeting. He shall receive proposals for membership and bring them before the Standing Committee. He shall give to the Secretary of each Section the list of papers assigned to it by the Standing Committee.

Art. 13. The Permanent Secretary shall be the executive officer of the Association under the direction of the Standing Committee. He shall attend to all business not specially referred to committees nor otherwise constitutionally provided for. He shall keep an account of all business that he has transacted for the Association, and make annually at the first meeting of the Standing Committee, a report which shall be laid before the Association. He shall attend to the printing and distribution of the annual volume of Proceedings, and all other printing ordered by the Association. He shall issue a circular of information to members and fellows at least four months before each meeting, and shall, in connection with the Local Committee, make all necessary arrangements for the meetings of the Association. He shall provide the Secretaries of the Association with such books and stationery as may be required for their records and business, and shall provide members and fellows with such blank forms as may be required for facilitating the business of the Association. He shall collect all assessments and admission fees, and notify members and fellows of their election, and of any arrearages. He shall receive, and bring before the Standing Committee, the titles and abstracts of papers proposed to be read before the Association. He shall keep an account of all receipts and expenditures of the Association, and report the same annually at the first meeting of the Standing Committee, and, at the close of each year, shall pay over to the Treasurer such unexpended funds as the Standing Committee may direct. He shall receive and hold in trust for the Association all books, pamphlets and manuscripts belonging to the Association, and allow the use of the same under the provisions of the Constitution and the orders of the Standing Committee. He shall receive all communications addressed to the Association during the interval between meetings, and properly attend to the same. He shall at each meeting report the names of fellows and members who have died since the preceding meeting. He shall be allowed a salary which shall be determined by the Standing Committee, and may employ a clerk at such compensation as may be agreed upon by the Standing Committee.

Art. 14. The Treasurer shall invest the funds received by him in such securities as may be directed by the Standing Committee. He shall annually present to the Standing Committee an account of the funds in his charge. No expenditure of the principal in the hands of the Treasurer shall be made without a unanimous vote of the Standing Committee, and no expenditure of the income received by the Treasurer shall be made without a two-thirds vote of the Standing Committee.

Art. 15. The Secretaries of Sections A and B shall keep the records of their respective sections, and, at the close of the meeting, give the same, including the records of subsections, to the General Secretary. They shall also be the secretaries of the sectional committees.

Art. 16. In case of a vacancy in the office of the President, one of the Vice Presidents shall be elected by the Standing Committee as the President of the meeting. Vacancies in the offices of Vice President, General Secretary, Permanent Secretary and Treasurer, shall be filled by nomination of the Standing Committee and election by ballot in general session. A vacancy in the office of Secretary of a Section shall be filled by nomination and election by ballot in the section.

Art. 17. The Standing Committee shall consist of the past Presidents, the President, the Vice Presidents, the four Secretaries, the Treasurer, with the above named officers of the preceding meeting, and six fellows elected by ballot after open nomination at the first general session. The members present at any regularly called meeting of the Committee, provided there are at least five, shall form a quorum for the transaction of business. The Standing Committee shall meet on the day preceding each annual meeting of the Association, and arrange the programme for the first day of the sessions. The time and place of this first meeting shall be designated by the Permanent Secretary. Unless otherwise agreed upon, regular meetings of the Committee shall be held in the committee room at 9 o'clock, A.M., on each day of the meeting of the Association. Special meetings of the Committee may be called at any time by the President. The Standing Committee shall be the board of supervision of the Association, and no business shall be transacted by the Association that has not first been referred to, or originated with, the Committee. The special business of the Committee shall be: to receive and assign papers to the respective sections; to examine and, if necessary, to exclude papers; to decide which papers, discussions and other proceedings shall be published, and to have the general direction of

the publications of the Association; to manage the financial affairs of the Association; to arrange the business and programmes for general sessions; to appoint general sessions for the evening; to suggest subjects for discussion, investigation or reports; to nominate members and fellows; to receive and act upon all invitations extended to the Association and report the same at a general session of the Association.

ART. 18. The Nominating Committee shall consist of the Standing Committee, and four members or fellows elected by each of the sections. It shall be the duty of this Committee to meet at the call of the President and nominate the general officers for the following meeting of the Association. It shall also be the duty of this Committee to recommend the time and place for the next meeting. The Vice Presidents and Secretaries of the Sections shall be recommended to the Nominating Committee by sub-committees consisting of the Vice Presidents and Secretaries, and the four persons elected by each section under the first clause of this article.

MEETINGS.

ART. 19. The Association shall hold public meetings annually, for one week or longer, at such time and place as may be determined by vote of the Association, and the preliminary arrangements for each meeting shall be made by the Local Committee, in conjunction with the Permanent Secretary and such other persons as the Standing Committee may designate.

ART. 20. General Sessions shall be held at 10 o'clock, A. M., unless otherwise ordered, on every day of the meeting, Sunday excepted, and at such other times as may be appointed by the Standing Committee.

SECTIONS AND SUBSECTIONS.

ART. 21. The Association shall be divided into two Sections, namely: A (*Mathematics*, *Astronomy*, *Physics*, *Chemistry* and *Mineralogy*) and B (*Geology*, *Zoology*, *Botany* and *Anthropology*). Either Section may, at its pleasure, form temporary or permanent subsections for the reading of papers.

ART. 22. Immediately on the organization of a Section there shall be three fellows elected by ballot after open nomination, who, with the Vice President and Secretary, and the Chairman and Secretary of the subsections, shall form its Sectional Committee. The Sectional Com-

mittees shall have power to fill vacancies in their own numbers. There shall be no sectional meeting during a general session.

ART. 23. When any Subsection organizes, it shall elect a Chairman and Secretary and report the result to the Secretary of its Section. The Secretary of a Subsection shall, at the close of the meeting, transmit his records to the Secretary of the Section. Any Permanent Subsection may elect its Chairman for the ensuing meeting.

ART. 24. No paper shall be read in any Section or Subsection until it has been placed on the programme of the day by the Sectional Committees.

SECTIONAL COMMITTEES.

ART. 25. The Sectional Committees shall arrange and direct the business of their respective sections. They shall prepare the daily programmes and give them to the Permanent Secretary for printing at the earliest moment practicable. No titles of papers shall be entered on the daily programmes except such as have passed the Standing Committee. No change shall be made in the programme for the day without the consent of the Sectional Committee. The Sectional Committees may refuse to place the title of any paper on the programme; but every such title, with the abstract of the paper or the paper itself must be returned to the Standing Committee with the reasons why it was refused.

ART. 26. The Sectional Committees shall examine all papers and abstracts referred to the sections, and they shall not place on the programme any paper inconsistent with the character of the Association; and to this end they have power to call for any paper, the character of which may not be sufficiently understood from the abstract submitted.

PAPERS AND COMMUNICATIONS.

ART. 27. All members and fellows must forward to the Permanent Secretary, as early as possible, and when practicable before the convening of the Association, full titles of all the papers which they propose to present during the meeting, with a statement of the time that each will occupy in delivery, and also such abstracts of their contents as will give a general idea of their nature; and no title shall be referred by the Standing Committee to the Sectional Committee until an abstract of the paper or the paper itself has been received.

ART. 28. If the author of any paper be not ready at the time assigned, the title may be dropped to the bottom of the list.

Reports of Meetings.

Art. 29. Whenever practicable, the proceedings and discussions at general sessions, sections and subsections shall be reported by professional reporters, but such reports shall not appear in print as the official reports of the Association unless revised by the secretaries.

Printed Proceedings.

Art. 30. The Permanent Secretary shall have the Proceedings of each meeting printed in an octavo volume as soon after the meeting as possible, beginning one month after adjournment. Authors must prepare their papers ready for the press and forward them to the Permanent Secretary within this interval, otherwise only the abstracts or titles will appear in the printed volumes. The Standing Committee shall have power to print an abstract only of any paper. Whenever practicable, proofs shall be forwarded to authors for revision. If any additions or substantial alterations are made by the author of a paper after its submission to the Secretary, the same shall be distinctly indicated. Illustrations must be provided for by the authors of the papers, or by a special appropriation from the Standing Committee. Immediately on publication of the volume, a copy shall be forwarded to every member and fellow of the Association who shall have paid the assessment for the meeting to which it relates, and it shall also be offered for sale by the Permanent Secretary at such price as may be determined by the Standing Committee. The Standing Committee shall also designate the institutions to which copies shall be distributed.

Local Committee.

Art. 31. The Local Committee shall consist of persons interested in the objects of the Association and residing at or near the place of the proposed meeting. It is expected that the Local Committee, assisted by the officers of the Association, will make all essential arrangements for the meeting, and issue a circular giving necessary particulars, at least one month before the meeting.

Library of the Association.

Art. 32. All books and pamphlets received by the Association shall be in the charge of the Permanent Secretary, who shall have a list of the same printed and shall furnish a copy to any member or fellow on application. Members and fellows who have paid their assessments in full

shall be allowed to call for books and pamphlets, which shall be delivered to them at their expense, on their giving a receipt agreeing to make good any loss or damage and to return the same free of expense to the Secretary at the time specified in the receipt given. All books and pamphlets in circulation must be returned at each meeting, or the value of any not so returned paid to the Permanent Secretary. Not more than ten books, including volumes, parts of volumes, and pamphlets, shall be held at one time by any member or fellow. Any book may be withheld from circulation by order of the Standing Committee.

Admission Fee and Assessments.

Art. 33. The admission fee for members shall be five dollars in addition to the annual assessment. On the election of any member as a fellow an additional fee of two dollars shall be paid.

Art. 34. The annual assessment for members and fellows shall be three dollars.

Art. 35. Any member or fellow who shall pay the sum of fifty dollars to the Association, at any one time, shall be exempt from all further assessments, but this payment shall not entitle him to the publications of the Association, and all money thus received shall be invested as a permanent fund, the income of which shall be used only to assist in original research.

Art. 36. All admission fees and assessments must be paid to the Permanent Secretary, who shall give proper receipts for the same.

Accounts.

Art. 37. The accounts of the Permanent Secretary and of the Treasurer shall be audited annually, by two auditors appointed by the Standing Committee.

Alterations of the Constitution.

Art. 38. No part of this Constitution shall be amended or annulled, without the concurrence of three-fourths of the members and fellows present in general session, after notice given at a general session of a preceding meeting of the Association.

ORDER OF PROCEEDINGS

IN

ORGANIZING A MEETING.

1. The retiring President introduces the President elect, who takes the chair.
2. Formalities of welcome of the Association as may be arranged by the Local Committee.
3. Report of the list of papers on the register and their reference to the Sections.
4. Other reports.
5. Announcements of arrangements by the Local Committee.
6. Elections to complete the Standing Committee.
7. Election of members.
8. Election of fellows.
9. Unenumerated business.
10. Adjournment to meet in Sections.

This order, so far as applicable, to be followed in subsequent General Sessions.

MEMBERS

OF THE

AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.[1]

PATRON.[2]

Thompson, Mrs. Elizabeth, Stamford, Conn. (22). (Entitled to Annual volume.)

LIFE MEMBERS.[3]

Case, Leonard, Cleveland, Ohio (15).
Elwyn, Alfred L., Philadelphia, Pa. (1).
Harkness, Prof. Wm., U. S. N., U. S. Observatory, Washington, D. C. (26).
Lyman, Benj. Smith, care Smith, Archer & Co., Yokohama, Japan (15).
Robertson, Thomas D., Rockford, Ill. (10).
Stephens, W. Hudson, Lowville, N. Y. (18). (Entitled to annual volume.)
Vaux, William S., 1702 Arch St., Philadelphia, Pa. (1). (Entitled to annual volume.)
Warner, James D., 199 Baltic St., Brooklyn, N. Y. (18).

MEMBERS.

Abbe, George W., 32 East 20th St., New York (23).
Abbott, Miss Elizabeth O., 16 Clark St., Cincinnati, Ohio (20).
Acheson, Edward G. (25).
Adcock, Prof. Robert J., Monmouth, Warren Co., Ill. (21).
Aikin, Prof. W. E. A., Baltimore, Md. (12).
Ainsworth, Frank B., Sup't Ind. House of Refuge, Plainfield, Ind. (20).

[1] The numbers in parentheses indicate the meeting at which the member was elected. The Constitution requires that the names of all members two or more years in arrears shall be omitted from the list, but their names will be restored on payment of arrearages. Members not in arrears are entitled to the annual volume of Proceedings.

[2] Persons contributing one thousand dollars or more to the Association are classed as Patrons, are exempt from the annual assessments and are entitled to the annual volume.

[3] Any Member or Fellow may become a Life Member by the payment of fifty dollars. The money derived from Life Membership is invested as a fund, the income of which is to be used only to aid in original research. Life Members are exempt from the annual assessment, and an additional payment of ten dollars entitles a Life Member to the annual volume.

Albert, Augustus J., Baltimore, Md. (12).
Alexander, Prof. Stephen, Princeton, N. J. (1).
Allen, H. R., Indianapolis, Ind. (24).
Allen, J. M., Hartford, Conn. (22).
Allen, Stephen M., 28 State St., Boston, Mass. (23).
Ammen, Daniel, Commodore U. S. Navy, Washington, D. C. (26).
Armsby, Henry P., Box 48, New Haven, Conn. (23).
Armstrong, Rev. John W., D.D., State Normal School, Fredonia, N. Y. (24).
Arthur, J. C., Charles City, Iowa (21).
Atchison, Prof. Thos. A., University of Nashville, Nashville, Tenn. (26).
Atkinson, Jno. B., Earlington, Hopkins Co., Ky. (26).
Atwater, Mrs. Samuel T., 166 Washington St., Chicago, Ill. (17).
Atwell, W. H., Care Atwell and Sneed, Nashville, Tenn. (26).
Austen, Peter T., Ph. D., Rutger's College, Lock Box No. 2, New Brunswick, N. J. (26).
Austin, Mrs. E. P., Cambridge, Mass. (24).

Babbitt, Henry S., M. D., Columbus, Ohio (23).
Babcock, Prof. Samuel S., Mt. Clemens, Macomb Co., Mich. (24).
Bailey, E. H. S., Bethlehem, Pa. (25).
Baird, Alexander J., D.D., Nashville, Tenn. (26).
Baker, Prof. Arthur L., Lafayette College, Easton, Pa. (24).
Baker, Prof. T. R., Millersville, Lancaster Co., Pa. (22).
Balch, David M., Salem, Mass. (22).
Bandelier, Ad. F., Highlands, Ill. (25).
Barber, Edwin A., Westchester, Chester Co., Pa. (25).
Barnard, Jas. M., Boston, Mass. (18).
Barnard, Wm. Stebbins, Canton, Ill. (24).
Barnard, Edward E., Nashville, Tenn. (26).
Barnett, Prof. Samuel, jr., Washington, Wilkes Co., Ga. (26).
Barry, Sir Redmond, President Public Library of Melbourne, Victoria, Australia (25).
Bassett, George W., M.D., Vandalia, Ill. (20).
Bassnett, Thomas, Jacksonville, Fla. (8).
Bassnett, Mrs. Thomas, Jacksonville, Fla. (24).
Bastian, Dr. David I., Clinton, Worcester Co., Mass. (25).
Bate, Gen. Wm. Brimage, Nashville, Tenn. (26).
Batterson, J. G., Hartford, Conn. (23).
Bausch, Edward, Rochester, N. Y. (26).
Beach, Charles M., Merchant, Hartford, Conn. (23).
Beach, J. Watson, Merchant, Hartford, Conn. (23).
Beach, William H., Beloit, Wis. (21).
Beal, Prof. Wm. James, Agricultural College, Lansing, Mich. (24).
Becker, Hon. Philip, Buffalo, N. Y. (25).
Bell, Prof. Alex. Graham, Boston University, Boston, Mass. (26).
Bell, John J., Exeter, N. H. (22).
Bemis, Hon. A. S., President of the Common Council, Buffalo, N. Y. (25).

Benjamin, E. B., 10 Barclay St., New York (19).
Bessels, Dr. Emil, Smithsonian Institution, Washington, D. C. (26).
Bessey, Prof. C. E., Agricultural College, Ames, Iowa (21).
Bicknore, Prof. Albert S., Am. Mus. of Nat. Hist., Central Park, N. Y. (17).
Bill, Charles, Springfield, Mass. (17).
Blackham, Dr. George E., Dunkirk, N. Y. (25).
Blair, Henry Wayne, U. S. Coast Survey, Lexington, Va. (26).
Blake, W. P., Geologist, New Haven, Conn. (2).
Blatchford, Eliphalet W., 375 North La Salle St., Chicago, Ill. (17).
Blois, John T., Jonesville, Hillsdale Co., Mich. (24).
Bohrer, Charles J., Lafayette, Ind. (25).
Bolles, Rev. E. C., Salem, Mass. (17).
Boss, Prof. Lewis, Director Dudley Observatory, Albany, N. Y. (26).
Bowen, Edmund S., General Supt. Erie Railway, New York (25).
Bowen, Lemuel W., care D. M. Ferry & Co., 203 Woodward Ave., Detroit, Mich. (24).
Bowles, Miss Margaretta, P. O. Box 25, Louisville, Ky. (26).
Bowron, James, Supt. Southern Mining Co., South Pittsburg, Tenn. (26).
Braden, John, D.D., Pres. Central College, Nashville, Tenn. (26).
Breneman, A. A., Ithaca, N. Y. (20).
Briggs, Albert D., 7 Fort Block, Springfield, Mass. (13).
Briggs, Charles S., Vanderbilt University, Nashville, Tenn. (26).
Brigham, Rev. Charles H., Ann Arbor, Mich. (17).
Brooks, Major Thos. B., Geologist State Surveys Mich. and Wis., Newburgh, N. Y. (26).
Broomall, Hon. John M., Media, Delaware Co., Pa. (23).
Brown, Mrs. Ashley, 115 Wilkinson St., Dayton, Ohio (25).
Brown, Hon. John C., Vice President, Texas and Pacific R. R. Co., Pulaski, Tenn. (26).
Brown, Rev. John Reese, D.D., Nashville, Tenn. (26).
Brush, Dr. Edward N., Buffalo, N. Y. (25).
Bryan, Malachi Thomas, Nashville, Tenn. (26).
Bryan, Oliver N., Accokeek P. O., Prince George's Co., Md. (18).
Buckhout, W. A., State College, Centre Co., Pa. (20).
Buist, John Robinson, M. D., Pres. Nashville Board of Health, Nashville, Tenn. (26).
Bull, Dr. Alexander T., 98 Swan St., Buffalo, N. Y. (25).
Bush, Stephen, Waterford, N. Y. (19).

Cadman, Charles C., Merchants' & Manufacturers' Bank, Detroit, Mich. (24).
Caldwell, John W., M.D., Stewart College, Clarksville, Tenn. (26).
Calthrop, Rev. S. R., Syracuse, N. Y. (25).
Campbell, A. C., Nashville, Tenn. (26).
Campbell, Mrs. Mary H., Crawfordsville, Ind. (22).
Canby, William M., 1101 Delaware Avenue, Wilmington, Del. (17).
Canfield, Rev. Eli H., D.D., Arlington, Bennington Co., Vt. (25).

Capen, Miss Bessie T., Smith College, Northampton, Mass. (23).
Carpenter, Prof. G. C., Simpson Centenary College, Indianola, Iowa (22).
Carrington, Col. Henry B., U.S.A., Prof. in Wabash College, Crawfordsville, Ind. (20).
Case, L. B., Richmond, Indiana (17).
Cassino, S. E., Naturalists' Agency, Salem, Mass. (25).
Caswell, John H., 11 West 48th Street, New York (26).
Cattell, William C., President Lafayette College, Easton, Pa. (15).
Chandler, Henry, Lewis Block, Buffalo, N. Y. (25).
Chapman, F. M., Danforth, Iroquois Co., Ill. (17).
Chase, Prof. F. A., Fisk University, Nashville, Tenn. (26).
Chase, Prof. Pliny E., Haverford College, Haverford, Pa. (18).
Chase, R. Stuart, 16 Merrimack St., Haverhill, Mass. (18).
Chase, Theodore R., Detroit, Mich. (24).
Choate, Prof. Isaac B., Buchtel College, Akron, Ohio (25).
Clark, Simeon T., M.D., Lockport, Niagara Co., N. Y. (25).
Clinton, Hon. George W., Buffalo, N. Y. (25).
Coe, Miss Emily M., 33 West 45th St., New York (25).
Coffinberry, W. L., Grand Rapids, Mich. (20).
Cogswell, Dr. George, Bradford, Mass. (18).
Collin, Prof. Alonzo, Cornell College, Mount Vernon, Iowa (21).
Colman, Henry, M.D., 1483 Washington St., Boston, Mass. (25).
Colton, G. Woolworth, 172 William St., New York (22).
Colyar, John B., Nashville, Tenn. (26).
Cook, Prof. A. J., Agricultural College, Lansing, Mich. (24).
Cook, Dr. Charles D., 133 Pacific St., Brooklyn, N. Y. (25).
Cooke, Caleb, Peabody Academy of Science, Salem, Mass. (18).
Cooley, Prof. Le Roy C., Vassar College, Poughkeepsie, N. Y. (19)
Copes, Dr. Joseph S., New Orleans, La. (11).
Corwin, Richard W., Michigan University, Ann Arbor, Mich. (24).
Coxe, Eckley B., Drifton, Jeddo P. O., Luzerne Co., Pa. (23).
Crehore, John D., 458 Prospect St., Cleveland, Ohio (24).
Cross, Japheth, Adrian, Mich. (24).
Cummings, John. Woburn, Mass. (18).
Curtis. Rev. W. S., D.D., Rockford, Ill. (21).
Cusick, Cornelius C., Lieut. 22nd Reg. Infantry, U.S.A., Washington, D. C. (24).
Cutter, John D., 1208 Pacific St., Brooklyn, L. I. (23).

Dake, J. P., M.D., 47 North Vine St., Nashville, Tenn. (26).
Davis, George T., Portland, Me. (23).
DeCamp, Dr. William H., Grand Rapids, Mich. (21).
Delano, Joseph C., New Bedford, Mass. (5).
Detviller, H J., Bethlehem, Pa. (26).
Devereux, J. H., President C.C.C. & I.R.R., Cleveland, Ohio (18).
DeWitt, Marcus Bearden, Nashville, Tenn. (26).

Dinwiddie, Prof. James, Clarksville, Tenn. (26).
Dixwell, Epes S., Cambridge, Mass. (1).
Dodd, C. M., Williamstown, Mass. (19).
Doggett, Mrs. Kate N., Chicago, Ill. (17).
Doggett, Wm. E., Chicago, Ill. (17).
Doolittle, Prof. C. L., South Bethlehem, Pa. (25).
Dorr, Capt. E. P., 280 Niagara St., Buffalo, N. Y. (25).
Doughty, John W., Newburgh, N. Y. (19).
Douglas, Prof. Samuel T., Ann Arbor, Mich. (24).
Douglas, Prof. Silas H., Ann Arbor, Mich. (24).
Draughon, John A., M.D., Nashville, Tenn. (26).
Drowne, Charles, care William L. Drowne, Esq., Canaan Four Corners, New York (6).
Drumm, Rev. Thomas, St. Mark's School, Rochester, N. Y. (25).
Dudley, Charles B., Altoona, Pa. (23).
Dunnington, Prof. F. P., University of Virginia, Charlottesville, Va. (26).
Duschak, Adolf, 13 Chippewa St., Buffalo, N. Y. (25).
Dyer, Clarence, Lawrence, Mass. (22).
Dyer, Elisha, 26 Westminster St., Providence, R. I. (9).

Eakin, John H., M. A., Nashville, Tenn. (26).
East, Addison A., M.D., Supt. University Hospital, Nashville, Tenn. (26).
Eastman, Prof. J. R., U. S. Naval Observatory, Washington, D. C. (26).
Eaton, Hon. John, U. S. Commiss'r of Education, Washington, D. C. (25).
Edgar, Col. George M., Principal of Edgar Institute, Paris, Ky. (20).
Edwards, A. Mead, M.D., Berkeley, Alameda Co., Cal. (18).
Elliott, Arthur H., Highlands Chem. and Mining Co., Highlands Station, Putnam Co., N. Y. (23).
Elliott, George B., Nashville, Tenn. (26).
Ellis, Wm. Hodgson, Trinity College, Toronto, Canada (25).
Emmerton, Mrs. W. H., Salem, Mass. (26).
Emmons, S. F., P. O. Box 2218, Cheyenne, Wyoming Territory (26).
Endemann, Hermann, Ph. D., Ass't Sanitary Inspector, 128 Worth St., New York (26).
Engelmann, Dr. Geo. J., 3003 Locust St., St. Louis, Mo. (25).
Enloe, Thos. E. M.D., Nashville, Tenn. (26).
Ennis, Jacob. Principal Scientific Inst., Philadelphia, Pa. (19).
Evans, Thos. Wyche, jr., Nashville, Tenn. (26).
Everts, Miss M. M., care Rev. W. W. Everts, D.D., Chicago, Ill. (22).

Faries, R. J., Wauwatosa, Wis. (21).
Farnam, Charles H., New Haven, Conn. (25).
Farnam, Prof. J. E., Georgetown, Ky. (26).
Farquharson, Dr. Robert James, Davenport, Iowa (24).

Fernald, Prof. Charles H., State Agricultural College, Orono, Me. (22).
Fernald, Prof. M. C., State Agricultural College, Orono, Me. (22).
Ficklin, Prof. Joseph, University of Missouri, Columbia, Mo. (20).
Fisher, Prof. Davenport, 642 Marshall St., Milwaukee, Wis. (17).
Fite, C. C., M.D., Shelbyville, Tenn. (26).
Fletcher, Ingram, care Fletcher & Sharpe, Indianapolis, Ind. (20).
Flint, D. B., Watertown, Mass. (25).
Ford, Albert C., U. S. Signal Service, Nashville, Tenn. (26).
Foreman, Henry L., U. S. Signal Service, Washington, D. C. (23).
Forshey, Col. C. G., New Orleans, La. (21).
Fosgate, Dr. Blanchard, Auburn, N. Y. (7).
Foster, Henry, M.D., Clifton, N. Y. (17).
Foster, Prof. Robert V., Lebanon, Wilson Co., Tenn. (26).
Foster, Wilbur F., Nashville, Tenn. (26).
Frazer, Prof. Persifor, jr., Ass't Geologist 2nd Geol. Survey of Pa., 917 Clinton St., Philadelphia, Pa. (24).
Frazier, Prof. B. W., The Lehigh University, Bethlehem, Pa. (24).
French, Dr. Geo. F., 666 Congress St., Portland, Me. (22).
Frothingham, Rev. Frederick, Milton, Mass. (11).
Fuller, A. S., Ridgewood, Bergen Co., N. J. (24).
Fulton, Prof. Robert B., University of Mississippi, Oxford, Miss. (21).

Gale, Dr. Edward R., Nashville, Tenn. (26).
Garbett, Wm. A., 8 and 10 Guild Building, Boston Highlands, Mass. (22).
Gardner, James T., Am. Geog. Soc., 11 W. 29th St., New York (25).
Garnett, Algernon S., M.D., Hot Springs, Arkansas (23).
Garrett, Ellwood, Wilmington, Newcastle County, Del. (22).
Gaskill, Joshua, Lockport, N. Y. (22).
Gatling, Dr. R. J., Hartford, Conn. (23).
Gattinger, August, M.D., Nashville, Tenn. (26).
Gerard, Aristide, New Orleans, La. (26).
Gibbs, Col. Charles N., Sec'y of State, Nashville, Tenn. (26).
Gibbs, R. M. W., Kalamazoo, Mich. (24).
Glenny, William H., jr., Buffalo, N. Y. (25).
Gold, Theodore S., West Cornwall, Conn. (4).
Goldschmidt, S. A., 59 & 61 Liberty St., New York (24).
Gooch, Frank A., Cambridge, Mass. (25).
Goodfellow, Edward, U. S. Coast Survey Office, Washington, D. C. (24).
Goold, W. N. (22).
Gould, Prof. B. A., care H. McMurtrie, P. O. Box 2414, Boston, Mass. (2).
Gould, Sylvester C., Manchester, N. H. (22).
Graham, Rev. William, Nashville, Tenn. (26).
Grant, J. F., M.D., Pulaski, Giles Co., Tenn. (26).
Green, J. C., M.D., Buffalo, N. Y. (25).
Green, Dr. Samuel E., 25th St., Pittsburgh, Pa. (22).
Greene, Jacob L., Sec. Mut. Life Ins. Co., Hartford, Conn. (23).
Gregory, Prof. J. J. H., Marblehead, Mass. (18).

Gridley, Albert L., Benzonia, Mich. (25).
Grinnell, George Bird, Yale College Museum, New Haven, Conn. (25).
Grossklaus, John F., Navarre, Ohio (24).
Gundlach, Ernst, Rochester, N. Y. (25).
Gunning, William D., Waltham, Mass. (22).

Haggard, W. D., M.D., Nashville, Tenn. (26).
Hague, Arnold, 23 Fifth Ave., N. Y. (26).
Hall, Israel, Ann Arbor, Mich. (24).
Hamel, Prof. Thomas E., Laval University, Quebec, Canada (18).
Hanaman, C. E., Troy, N. Y. (19).
Harger, Oscar, Yale College Museum, New Haven, Conn. (25).
Hart, Rev. Prof. Samuel, Trinity College, Hartford, Conn. (22).
Harvey, Charles W., Sup't Public Schools, Greensburg, Ind. (20).
Harvey, Dr. Leon F., Buffalo, N. Y. (22).
Hastings, Charles S., Johns Hopkins University, Baltimore, Md. (25).
Hatfield, Marcus P., M.D., Chicago Medical College, Chicago, Ill. (23).
Hawkins, Marion S., 60 High St., Nashville, Tenn. (26).
Hayes, George E., 1125 Main Street, Buffalo, N. Y. (15).
Hazen, E. H., M.D., Davenport, Iowa (25).
Henderson, John G., Winchester, Ill. (25).
Hensel, Martin, Columbus, Ohio (25).
Herdman, W. J., Ann Arbor, Mich. (24).
Hervey, Rev. A. B., Troy, N. Y. (22).
Hicks, John D., Old Westbury, Queen's Co., L. I. (23).
Higgins, F. W., Detroit, Mich. (24).
Higginson, John A., 260 Clarendon St., Boston, Mass. (26).
Hinds, Prof. J. I. D., Cumberland University, Lebanon, Tenn. (26).
Hogg, Prof. Alexander, College Station, Brazos Co., Texas (26).
Holbrook, Francis N., E. M., School of Mines, Columbia College, New York (26).
Holley, George W., Niagara Falls, N. Y. (19).
Holmes, John C., Room No. 4 Moffat Block, Detroit, Mich. (24).
Holmes, Henry A., Librarian State Library, Albany, N. Y. (11).
Hopkirk, Prof. W. H., Burlington, Iowa (24).
Hornaday, William T., Rochester, N. Y. (25).
Horr, Asa, M.D., Dubuque, Iowa (21).
House, John C., Union Gas Works, Waterford, N. Y. (19).
Houston, George M., Harrisonville, Mo. (26).
Howard, Miss Catharine L., Springfield, Mass. (25).
Howe, Dr. Lucien, 9 Niagara St., Buffalo, N. Y. (25).
Howell, Edwin E., Rochester, N. Y. (25).
Hoyte, James W., M.D., Nashville, Tenn. (26).
Hubbard, George W., M.D., Nashville, Tenn. (26).
Hubbard, H. G., Detroit, Mich. (24).
Hubbard, Mrs. Sara A., 31 Thirty-third St., Chicago, Ill. (17).

Humphrey, D., M.D., Lawrence, Mass. (18).
Humphreys, A. W., Box 1384, New York (20).
Hunt, Miss Sarah E., Salem, Mass. (20).
Hunting, Rev. S. S., Pres. Davenport Academy Natural Sciences, Davenport, Iowa (26).
Huntington, Prof. Chester, Clinton, Oneida Co., N. Y. (26).
Hyde, E. W., University of Cincinnati, Cincinnati (25).

Ingram, Mrs. A., Nashville, Tenn. (26).
Irish, Thomas M., 58 Prairie St., Dubuque, Iowa (21).
Irving, Roland D., Wisconsin State Geological Survey, Madison, Wis. (26).
Isawa, Shuje, care G. Attwood, 53 State St., Boston, Mass. (26).
Isom, John F., Cleveland, Ohio (24).

Jackson, Thomas J., Nashville, Tenn. (26).
James, Frederick H., M.D., Lancaster, N. Y. (25).
James, Thomas Potts, Cambridge, Mass. (22).
Jarvis, George C., M.D., Hartford, Conn. (23).
Jasper, Gustavus A., 12 Central St., Boston, Mass. (18).
Jewell, Pliny, Mineralogical Amateur, Hartford, Conn. (23).
Jewell, Lt. Comdr. Theo. F., U.S.N., Annapolis, Md. (25).
Jillson, Dr. B. C., Pittsburg, Pa. (14).
Johnson, Prof. Hosmer A., Academy of Sciences, Chicago, Ill. (22).
Johnston, J. Frank, Bethlehem, Pa. (25).
Jones, Prof. Richard W., University of Mississippi, Oxford, Miss. (25).
Jones, Dr. William L., Ed. Southern Cultivator, Athens, Ga. (26).
Jones, Wm. P., M.D., Pres. Nashville Med. College, Nashville, Tenn. (26).
Joy, Prof. Charles A., Stockbridge, Mass. (8).

Keely, Prof. G. W., Waterville, Me. (1).
Kellogg, John H., M.D., Battle Creek, Mich. (24).
Kent, William, Pittsburgh, Pa. (26).
Killebrew, J. B., Commissioner of Agriculture, Nashville, Tenn. (26).
Kinder, Miss Sarah, 27 Lockerbie St., Indianapolis, Ind. (20).
King, Clarence, U. S. Geol. Expl. of the 40th Parallel, 23 Fifth Ave., New York (26).
King, Ephraim L., M.D., Box 251, Ashtabula, Ohio (24).
King, Mrs. Mary B. A., 21 Madison St., Rochester, N. Y. (15).
Kinner, Dr. Hugo, 1517 South Seventh St., St. Louis, Mo. (21).
Kirkpatrick, James A., 19 South Fifth St., Philadelphia, Pa. (7).
Kirkpatrick, Prof. Richard L., Knoxville, Tenn. (26).
Kite, Thomas, Gen'l Agent Washington Life Ins. Co. of N. Y., 122 Vine St., Cincinnati, O. (5).
Klippart, John H., Cor. Sec'y State Board of Agriculture, Box 1453, Columbus, Ohio (17).

Knapp, Frederick N., Plymouth, Mass. (19).
Kneeland, Dr. Samuel, Mass. Institute Technology, Boston, Mass. (20).
Knight, J. B., care Franklin Institute, Philadelphia, Pa. (21).
Koesis, Alexander, Tullahoma, Ala. (26).

Lakes, Prof. Arthur, Morrison, Colorado (26).
Land, William J., P. O. Box 305, Atlanta, Ga. (25).
Lawrence, Hon. Edw., Pres't Bunker Hill National Bank, Charlestown, Mass. (18).
Lea, John McCormack, Nashville, Tenn. (26).
Ledoux, Albert R., Ph. D., State Chemist, Chapel Hill, N. C. (26).
Leland, Eugene R., Eau Claire, Wis. (25).
Lesley, Joseph, 233 South Fourth St., Philadelphia, Pa. (8).
Letchworth, Josiah, Buffalo, N. Y. (25).
Lewis, Elias, jr., 111 St. Mark's Ave., Brooklyn, N. Y. (23).
Lewis, George A., 10 Lewis Block, Buffalo, N. Y. (25).
Lewis, Henry C., E. Washington Lane, Germantown, Pa. (26).
Lewis, James, Mohawk, N. Y. (25).
Lindsley, Adrian Van S., Sec'y University of Nashville, Tenn. (26).
Lindsley, Adrian Van S., jr., Nashville, Tenn. (26).
Lindsley, Miss Louise, Nashville, Tenn. (26).
Lindsley, Miss Mary McG., Nashville, Tenn. (26).
Lindsley, Van Sinderen, M.D., Nashville, Tenn. (26).
Losey, L. L., Nashville, Tenn. (26).
Loudon, Prof. James, Toronto, Canada (25).
Love, Edward G., School of Mines, Columbia College, New York (24).
Lovewell, Prof. Joseph T., State College, Centre Co., Pa. (25).
Lowry, Prof. Thos. J., Columbia P. O., Boone Co., Mo. (26).
Lunn, Miss Emma, Montreal, Canada (24).
Lyford, Prof. Moses, Waterville, Me. (22).

MacArthur, Charles L., Troy, N. Y. (19).
Mack, William, M.D., Salem, Mass. (21).
Macloskie, Prof. George, College of New Jersey, Princeton, N. J. (25).
Macy, Arthur, M. E., 26 Cedar Street, New York (26).
Maghee, J. Holme, 16 East 54th St., New York (26).
Mallery, Brevet Lieut. Col. Garrick, Captain 1st Infantry, U. S. Army, detailed with the U. S. Geogr. and Geol. Surv., Rocky Mt. Region, Washington, D. C. (26).
Mansfield, J. M., Mt. Pleasant, Iowa (25).
Marden, Geo. H., 7 Parker St., Charlestown, Mass. (18).
Mark, Edward L., Fredonia, N. Y. (21).
Martin, Prof. B. N., 236 W. 4th St., New York (23).
Martin, Prof. Daniel S., Rutger's Female College, New York (23).
Martindale, Isaac C., 322 Penn St., Camden, N. J. (26).
Mathews, Robert, 28 Spring St., Rochester, N. Y. (25).

Maxwell, J. M. (24).
Maycock, Prof. M. M., Buffalo, N. Y. (25).
McClung, Calvin M., Knoxville, Tenn. (26).
McCutchen, Aug. R., Dalton, Ga. (25).
McMurtrie, Horace, P. O. Box 2414, Boston, Mass. (17).
McNeal, Albert T., Bolivar, Tenn. (26).
McRae, John, Camden, S. C. (3).
McWhorter, Tyler. Aledo, Ill. (20).
Metcalf, Caleb B., Highland Military Academy, Worcester, Mass. (20).
Michelson. A. A., Ensign U. S. Navy, Annapolis, Md. (26).
Milburn, John G., Buffalo, N. Y. (25).
Miller, John A., Box 110, Paducah, Ky. (22).
Miller, S. A., Cincinnati, Ohio (26).
Minifie, William, 114 Baltimore St., Baltimore, Md. (12).
Moffatt, Dr. George T., Boston, Mass. (25).
Moody, Mrs. Mary B., 187 N. Pearl St., Buffalo, N. Y. (25).
Moore, Edward M., M.D., Rochester, N. Y. (25).
Morehouse, Geo. W., Wayland. Steuben Co., N. Y. (24).
Morison, Dr. N. H., Provost of Peabody Institute, Baltimore, Md. (17).
Morris, John B., Nashville, Tenn. (26).
Moses, Prof. Thos. F., Urbana University, Urbana, Ohio (25).
Mudge, Benjamin F., Manhattan, Riley Co., Kansas (25).
Muir, John, 1419 Taylor St., San Francisco, Cal. (22).
Mulford, S. P., Marysville, Ohio (24).
Munroe, Prof. Henry S., School of Mines, Columbia College, N. Y. (26).
Murray, Charles H., Louisville, Clay Co., Ill. (24).

Nelson, Anson, Recording Sec'y Tenn. Hist. Society, Nashville, Tenn. (26).
Newman, John S., 48 East Washington St., Indianapolis, Ind. (20).
Newman, Mrs. John S., 48 East Washington St., Indianapolis, Ind. (21).
Newton, Rev. John, Mary Esther, West Fla. (7).
Nichols, Charles A., Providence, R. I. (17).
Nicholson, Prof. Hunter, Knoxville, Tenn. (26).
Nicholson, Thomas, M.D., 490 Magazine St., New Orleans, La. (21).
Norwood, Charles J., Ass't Kentucky Geological Survey, Russellville, Kentucky (26).
Nowlin, John B. W., M.D., Nashville, Tenn. (26).
Noyes, Dr. James F., 101 Shelby St., Detroit, Mich. (24).

Ogden, Mahlon D., Chicago, Ill. (17).
Olmsted, Fred. Law, Commissioner of Public Parks, 209 W. 46th St., New York (22).
Ordway, Prof. John M., Mass. Inst. Technology, Boston, Mass. (9).
Osborne, Mrs. Ada M., Waterville, Oneida Co., N. Y. (19).
Osborne, Amos O., Waterville, Oneida Co., N. Y. (19).

Paine, Charles, Gen. Supt. Lake Shore & Southern Railway Co., Cleveland, Ohio (22).
Palmer, Rev. Benj. M., Box 1762, New Orleans, La. (21).
Palmer, Dr. Edward, care Peabody Museum, Cambridge, Mass. (22).
Parvin, Theodore S., Iowa City, Iowa (7).
Patterson, James S., Nashville, Tenn. (26).
Patterson, John P., Supt. Instruction, Washington C. H., Ohio (25).
Paul, Caroline A., M.D., Vineland, Cumberland Co., N. J. (23).
Peabody, Prof. F. Downing, Hopkinsville, Ky. (26).
Peck, W. A., C. E., Idaho Springs, Clear Creek Co., Col. (19).
Peet, Rev. Stephen D., Ashtabula, Ohio (24).
Peirce, Prof. Benjamin, Cambridge, Mass. (1).
Percival, Rev. Chester S., Rockford, Ill. (21).
Perkins, Prof. George H., Burlington, Vt. (17).
Perkins, T. Lyman, Salem, Mass. (22).
Phelps, Gen. Charles E., Baltimore, Md. (13).
Phelps, Mrs. Almira Lincoln, Baltimore, Md. (13).
Philbrick, Prof. Philetus H., Iowa City, Iowa (23).
Phillips, A. W., Cheshire, Conn. (24).
Phillips, Prof. Charles, Univ. of North Carolina, Chapel Hill, N. C. (25).
Phin, John, Ed. Am. Journ. Microscopy, 176 Broadway, New York (25).
Pickett, Dr. Thos. E., Maysville, Mason Co., Ky. (25).
Pigue, Edward H., Nashville, Tenn. (26).
Pillsbury, John H., 58 Pynchon St., Springfield, Mass. (23).
Pitt, Prof. William H., Buffalo, N. Y. (25).
Plunket, James D., M.D., Pres. State Bd. of Health, Nashville, Tenn. (26).
Porteous, John, 26 Prince Arthur Street, Montreal, Canada (22).
Porter, F. T., Nashville, Tenn. (26).
Potter, Prof. William B., Washington University, St. Louis, Mo. (25).
Pratt, William H., 513 Perry St., Davenport, Iowa (17).
Preston, Prof. W. C., Laboratory, Iowa State Univ., Iowa City, Iowa (21)
Prichitt, Samuel, Nashville, Tenn. (26).
Prince, Gen. Henry, U.S.A., Headquarters of the Army, San Francisco, Cal. (22).
Proctor, John R., Ass't Ky. Geol. Survey, Frankfort, Ky. (26).
Prosser, Wm. F., Nashville, Tenn. (26).
Pruyn, John V. L., Chancellor Univ. of N. Y., 13 Elk St., Albany, N. Y. (1).
Pulsifer, Sidney, Peoria, Ill. (21).
Pulsifer, Wm. H., St. Louis, Mo. (26).
Putnam, Mrs. F. W., Cambridge, Mass. (19).
Putnam, George P., Buffalo, N. Y. (25).

Ramsdell, Hon. J. G., Traverse City, Mich. (24).
Rau, Dr. Charles, Smithsonian Institution, Washington, D. C. (24).
Rees, Prof. John K., Washington University, St. Louis, Mo. (26).
Richards, Mrs. Robert H., Mass. Inst. of Technology, Boston, Mass. (23).

Ricketts, Pierre de Peyster, Ph.D., School of Mines, Columbia College, New York (26).
Riggs, Geo. W., jr., Washington University, St. Louis, Mo. (26).
Rivers, E. R., Agricultural and Mechanical College, Auburn, Ala. (26).
Robertson, Col. Robert S., Fort Wayne, Ind. (20).
Robinson, Henry C., Lawyer, Hartford, Conn. (23).
Robinson, Prof. Otis Hall, Rochester, N. Y. (23).
Rockwell, Alfred P., Eastern R. R., Boston, Mass. (10).
Rodgers, Rear Adm. C. R. P., Supt. Naval Academy, Annapolis, Md. (26).
Rogers, A. J., Milwaukee, Wis. (25).
Rogers, Hon. Sherman S., Buffalo, N. Y. (25).
Rominger, Carl, M.D., Ann Arbor, Mich. (21).
Root, Prof. Elihu, Amherst College, Amherst, Mass. (25).
Rose, Prof. P. B., Ann Arbor, Mich. (23).
Rosenspitz, Rev. Alexander, Nashville, Tenn. (26).
Rumsey, Bronson C., 58 and 60 Exchange St., Buffalo, N. Y. (15).
Russell, I C., School of Mines, New York (25).
Russell, L. W., Providence, R. I. (20).
Russell, W. H. H., 322 Chestnut St., cor. 4th, St. Louis, Mo. (24).
Rust, Horatio N., cor. Rush & Kinsie streets, Chicago, Ill. (26).

Safford, Charles W., Rutland, Vt. (26).
Sage, John H., Portland, Conn. (23).
Sampson, Com'd W. T., U.S.N., Naval Academy, Annapolis, Md. (25).
Sanders, Benjamin D., Wellsburg, Brooke County, W. Va. (19).
Scammon, J. Young, Chicago, Ill. (17).
Schaeck, Prof. J. Stillwell, Princeton, New Jersey (4).
Schmelter, Henry, P. O. Box 2135, New York (25).
Schmid, Dr. H. Ernest, White Plains, N. Y. (25).
Scobey, James E., Pres. Murfreesboro Fem. Inst., Murfreesboro, Tenn. (26).
Seaman, Ezra C., Ann Arbor, Mich. (20).
Seeley, Charles A., 26 Pine St., New York (18).
Seymour, Prof. William P., 105 Third St., Troy, N. Y. (19).
Sharp, Prof. Solomon Z., Maryville, Tenn. (26).
Sheafer, P. W., Pottsville, Pa. (4).
Sheafer, Walter S., Pottsville, Pa. (25).
Sheldon, Edwin H., Chicago, Ill. (17).
Shepherd, F. A., 21 North Vine Street, Nashville, Tenn. (26).
Shumard, Mrs. Elizabeth M., Shelbyville, Bedford Co., Tenn. (26).
Sill, J. M. B., Zoölogist, Detroit, Mich. (23).
Simonds, Frederic W., Prof. of Nat. History, Univ. of N. Carolina, Chapel Hill, N. C. (25).
Skinner, Joseph J., New Haven, Conn. (23).
Smith, Carlos G., Pres. University of Alabama, Tuscaloosa, Ala. (26).
Smith, Prof. F. H., University of Virginia, Charlottesville, Va. (26).
Smith, Henry L., P. O. Box 2056, New York (26).
Smith, Mrs. Henry L., P. O. Box 2056, New York (26).

Smith, Henry T., Buffalo, N. Y. (25).
Smith, Herbert W., Academy of Sciences, St. Paul, Minn. (26).
Smith, J. W., M.D., Charles City, Iowa (21).
Smith, Quintus C., M.D., Cloverdale, Sonoma Co., Cal. (26).
Smith, Robert D., Pres. Columbia Athenæum, Columbia, Tenn. (26).
Smith, Mrs. S. H., Jersey City, N. J. (25).
Smith, Mrs. Sarah J., Louisville, Ky. (26).
Smith, William Austin, M.D., Columbia, Tenn. (26).
Smith, W. H., 209 Jefferson Avenue, Detroit, Mich. (24).
Smith, Prof. William H., Nashville, Tenn. (26).
Smock, Prof. John Conover, Rutger's Coll., New Brunswick, N. J. (23).
Snively, Prof. John H., Nashville, Tenn. (26).
Snyder, Prof. Monroe B. (24).
Southworth, Mase S., Ph.D., Williamstown, Mass. (25).
Sprague, E. C., Buffalo, N. Y. (24).
Springer, Alfred, Cincinnati, Ohio (24).
Stearns, Eben S., Chancellor Univ. of Nashville, Nashville, Tenn. (26).
Stearns, Winfrid Alden, Amherst, Mass. (23).
Sternberg, George M., Surgeon U.S.A., Post Surgeon, Fort Walla Walla, W. T. (24).
Stevens, R. P., Jamaica, N. Y. (18).
Stevens, Thaddeus M., M.D., Indianapolis, Ind. (20).
Steward, A., Bridgeport, Conn. (21).
Stewart, Prof. Elliott W., Lake View, Erie Co., N. Y. (25).
Stimpson, Thomas M., Peabody, Mass. (18).
Stone, Miss Mary H., Salem, Mass. (25).
Storer, Dr. D. H , Boston, Mass. (1).
Storer, Prof. Frank H., Jamaica Plain, Mass. (13).
Stowell, John, 48 Main St., Charlestown, Mass. (21).
Straight, Prof. H. H., Oswego, N. Y. (25).
Strong, Prof. Edwin A., Grand Rapids, Mich. (24).
Stubbs, Prof. William C., Alabama Agricultural and Mechanical College, Auburn, Lee Co., Ala. (25).
Summers, Thos. O., M. D., Vanderbilt Univ., Nashville, Tenn. (22).
Sutton, Dr. George, Aurora, Dearborn Co., Ind. (20).
Swain, Mrs. James, Fort Dodge, Iowa (21).
Swasey, Oscar F., M.D., Beverly, Mass. (17).

Taylor, Wm. Curtis, 914 Chestnut St., Philadelphia, Pa. (24).
Thompson, Harvey M., Brevoort House, Chicago, Ill. (17).
Thompson, Robert H., 24 First St., Troy, N. Y. (19).
Thomson, Prof. A., Ames, Iowa (21).
Thurston, Gates P., Cor. Sec. Tenn. Hist. Society, Nashville, Tenn. (26).
Thurber, Miss Elizabeth, Plymouth, Mass. (22).
Tice, John H., St. Louis, Mo. (24).
Tittmann, Otto H., U. S. Coast Survey, Washington, D. C. (24).

Todd, Prof. James E., Tabor, Fremont Co., Iowa (22).
Tomlinson, Dr. J. M., 28 East Ohio St., Indianapolis, Ind. (20).
Toney, Rev. Thomas, Nashville, Tenn. (26).
Toombs, Robert, M. D., Washington, Ga. (26).
Townsend, Franklin, Adj. Gen. State of N. Y., Albany, N. Y. (4).
Townshend, Prof. N. S., Columbus, Ohio (17).
Trembley, J. B., M.D., Oakland, Alameda Co., Cal. (17).
Trowbridge, Mrs. L. H., 211 Jefferson Ave., Detroit, Mich. (21).
Tutwiler, Henry, Greene Springs, Ala. (26).
Twiss, George H., Columbus, Ohio (24).

Underwood, Rev. Dr. Walter, Fairfax, Vt. (26).
Upham, Dr. J. Baxter, 31 Chestnut St., Boston, Mass. (14).
Upham, Warren, Nashua, N. H. (25).

Vail, Prof. Hugh D., 1927 Mt. Vernon St., Philadelphia, Pa. (18).
Vasey, George, Department of Agriculture, Washington, D. C. (20).
Vaughn, Prof. William J., Franklin, Tenn. (26).

Wakeman, Thaddeus B., 93 Nassau St., New York (25).
Walcott, Charles D., Geological Rooms, Albany, N. Y. (25).
Walker, George C., 13 Chamber of Commerce, Chicago, Ill. (17).
Walker, N. B., 19 and 21 Cliff St., New York (20).
Wanzer, Ira, Brookfield, Conn. (18).
Ward, Lester F., Treasury Department, Washington, D. C. (26).
Ward, W. E., D D., President Ward's Seminary for Young Ladies, Nashville, Tenn. (26).
Warder, Robert B., North Bend, Hamilton Co., Ohio (19).
Wardwell, George J., Rutland, Vt. (20).
Warner, Mrs. J. D., 199 Baltic St., Brooklyn, N. Y. (21).
Warren, G. Washington, 54 Devonshire St., Room 1, Boston, Mass. (18).
Warring, Charles B., Croton Landing, N. Y. (25).
Watkins, Samuel, President Board of Education, Nashville, Tenn. (26).
Wead, Prof. Charles K., Malone, N. Y. (23).
Weakley, Richard W., Supt. Public Schools, Nashville, Tenn. (26).
Webb, Benjamin, jr., Salem, Mass. (18).
Webster, Prof. H. E., Union College, Schenectady, N. Y. (23).
Welch, Mrs. G. O., Lynn, Mass. (21).
Wells, George A., Troy, N. Y. (19).
Wells, Samuel, 31 Pemberton Square, Boston, Mass. (24).
Wendell, Emory, First National Bank, Detroit, Mich. (24).
West, Charles E., 138 Montagne St., Brooklyn, N. Y. (1).
Wharton, Prof. John C., Tenn. College of Pharmacy, Nashville, Tenn. (26).
Wheeler, Prof. C. G., University of Chicago, Chicago, Ill. (18).
Wheeler, Lt. Geo. M., U.S.E., Lock Box 93, Washington, D. C. (25).
Wheeler, Orlando B., Ass't U. S. Lake Survey, Detroit, Mich. (24).

Wheeler, Dr. T. B., 714 Craig St., Montreal, Canada (11).
White, Lieut. Com'd H. C., U. S. Navy, care W. I. Harris, Continental National Bank, New York (23).
White, Prof. I. C., University of W. Va., Morgantown, W. Va. (25).
White, John, Buffalo, N. Y. (25).
White, LeRoy S., Waterbury, Conn. (23).
White, Samuel S., Publisher Dental Cosmos, Chestnut St., cor. Twelfth, Philadelphia, Pa. (23).
White, Z. L., Washington, D. C. (26).
Whitney, Mary W., Waltham, Mass. (19).
Whitworth, John L., Nashville, Tenn. (26).
Wilder, Gen. John T., Chattanooga, Tenn. (26).
Wilkin, Daniel F., Nashville, Tenn. (26).
Willet, Prof. Joseph E., Mercer University, Macon, Ga. (25).
Williams, Charles H., Buffalo, N. Y. (25).
Williams, E. B., Strawberry Point, Iowa (24).
Williams, Edward H., jr., P. O. Box 271, Wilkes Barre, Pa. (25).
Williams, Frank, Buffalo, N. Y. (25).
Williams, H. S., Williams Brothers, Phenix Iron Works, Ithaca, N. Y. (18).
Williams, J. G., 224 South 11th St., Philadelphia, Pa. (19).
Williams, John T., Rafferty and Williams, Foot 44th St., East R., N. Y. (25).
Williams, P. O., M.D., Watertown, Jefferson Co., N. Y. (24).
Williams, Willoughby, Nashville, Tenn. (26).
Williamson, Lieut. Col. R. S., U. S. Engineers, Light House Engineer, San Francisco, Cal. (12).
Wills, A. W., corner Union and Cherry streets, Nashville, Tenn. (26).
Wilson, M. C., Russellville, Ala. (26).
Wilson, Walter T., Buffalo, N. Y. (25).
Wormley, Theodore G., University of Penn., Philadelphia, Pa. (20).
Worster, Joseph, M.D , 115 East Thirtieth St., New York (22).
Wright, Prof. Albert A., Oberlin College, Oberlin, Ohio (24).
Wright, Rev. William J., Carlisle, Pa. (25).
Wurtz, Henry, 12 Hudson Terrace, Hoboken, N. J. (10).

Yarnall, Prof. M., U. S. Navy, Washington, D. C. (26).
Yeatman, Prof. Joseph W., Nashville, Tenn. (26).
Young, William H., Bookseller, 8 and 9 First St., Troy, N. Y. (19).

Zalinski, Lieut. E. L., U. S. A., St. Augustine, Fla. (25).

[597 MEMBERS.]

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FELLOWS.

Abbe, Prof. Cleveland, Washington, D. C. (16).
Agassiz, Alexander, Curator Mus. Comp. Zoology, Cambridge, Mass. (18).
Alexander, John S., 1935 Arch St., Philadelphia, Pa. (20).
Allen, Joel A., Museum Comparative Zoology, Cambridge, Mass. (18).
Allen, Zachariah, Providence, R. I. (1).
Alvord, Benj., Paymaster General, U. S. Army, D. C. (17).
Andrews, Prof. E. B., Lancaster, Ohio (7).
Appleton, Prof. John H., Brown University, Providence, R. I. (22).
Austin, E. P., Cambridge, Mass. (18).

Bailey, Prof. Loring W., University of Fredericton, N. B. (18).
Bailey, W. W., 31 Market Square, Providence, R. I. (18).
Baird, Prof. S. F., Sec'y Smithsonian Institution, Washington, D. C. (1).
Bardwell, Prof. F. W., University of Kansas, Lawrence, Kan. (13).
Barker, Prof. G. F., University of Pennsylvania, Philadelphia, Pa. (13).
Barnard, F. A. P., President Columbia College, New York (7).
Barnard, Gen. J. G., U. S. Army, Army Building, New York (14).
Bassett, Homer F., Waterbury, Conn. (23).
Batchelder, Dr. J. H., Salem, Mass. (18).
Batchelder, John M., 3 Divinity Avenue, Cambridge, Mass. (8).
Bell, Samuel N., Manchester, N. H. (7).
Bethune, Rev. Chas. J. S., Trinity Coll. School, Port Hope, Canada (18).
Blackie, Geo. S., M. D., Nashville, Tenn. (26).
Blake, Clarence J., M. D., Hotel Berkeley, Boston, Mass. (24).
Blake, Eli W., New Haven, Conn. (1).
Blake, Prof. Eli W., jr., Providence, R. I. (15).
Blake, Francis, jr., Assistant U. S. Coast Survey, Newton Lower Falls, Mass. (23).
Bolton, Dr. H. Carrington, Trinity College, Hartford, Conn. (17).
Bouvé, Thomas T., Pres't Boston Soc. Nat. History, Boston, Mass. (1).
Bowditch, Henry I., M.D., 113 Boylston St., Boston, Mass. (2).
Brackett, Prof. C. F., College of New Jersey, Princeton, N. J. (19).
Brewer, Prof. Wm. H., Box 55, New Haven, Conn. (20).
Brocklesby, Prof. John, Trinity College, Hartford, Conn. (23).
Brooks, William K., Johns Hopkins University, Baltimore, Md. (23).
Bross, Hon. Wm., Chicago, Ill. (7).
Broun, Prof. W. LeRoy, Vanderbilt University, Nashville, Tenn. (25).
Brown, Robert, jr., Office Cincinnati Gas Light Co., Cincinnati, Ohio (11).
Brown, Mrs. Robert, jr., Cincinnati, Ohio (17).
Brush, Prof. George J., Yale College, New Haven, Conn. (4).
Burbank, L. S., Woburn, Mass. (18).
Burgess, Edward, Sec. Natural History Society, Boston, Mass. (22).
Burnham, S. W., 52 Vincennes Ave., Chicago, Ill. (25).
Bushee, Prof. James, Worcester, Mass. (9).

Caldwell, Prof. George C., Cornell University, Ithaca, N. Y. (23).
Carmichael, Prof. Henry, Bowdoin College, Brunswick, Me. (21).
Carpenter, Lieut. W. L., Dunkirk, N. Y. (24).
Carr, Lucien, Peabody Museum Arch. and Ethn., Cambridge, Mass. (25).
Carrier, Prof. Joseph C., President St. Mary's College, Galveston, Tex. (20).
Chadbourne, Prof. P. A., Pres't Williams Coll., Williamstown, Mass. (10).
Chamberlin, T. C., Beloit College, Beloit, Wis. (21).
Chandler, Prof. C. F., School of Mines, Columbia Coll., New York (19).
Chandler, Prof. W. H., The Lehigh University, Bethlehem, Pa. (19).
Chanute, O., care Erie Railway, New York (17).
Chesbrough, E. S., Chicago, Ill. (2).
Chickering, Prof. J. W., jr., Deaf Mute College, Washington, D. C. (22).
Clark, Prof. John E., Mathematics, Yale College, New Haven, Conn. (17).
Clarke, Prof. F. W., Cincinnati University, Cincinnati, Ohio (18).
Coffin, Prof. John H. C., U. S. Navy, Washington, D. C. (1).
Coffin, Selden J., Ph.D., Lafayette College, Easton, Pa. (22).
Collett, Prof. John, Indiana Survey, Newport, Ind. (17).
Comstock, Prof. M. L., Galesburg, Knox Co., Ill. (21).
Comstock, Theo. B., Ass't Prof. in charge of Geol. Dep't, Cornell University, Ithaca, N. Y. (24).
Cook, Prof. George H., Lock Box 5, New Brunswick, N. J. (18).
Cope, Prof. Edward D., 2100 Pine St., Philadelphia, Pa. (17).
Coues, Elliott, Surgeon U. S. Army, Smithsonian Institution, Washington, D. C. (25).
Cox, Prof. Edward T., State Geologist, Indianapolis, Ind. (19).
Craik, Robert, M.D., McGill University, Montreal, Canada (11).
Cramp, Rev. J. M., D.D., Wolfville, N. S. (11).
Crocker, Charles F., Lawrence, Mass. (22).
Crocker, Susan E., M.D., Lawrence, Mass. (21).
Cummings, Rev. Joseph, D.D., President Wesleyan University, Middletown, Conn. (13).
Curtis, Dr. Josiah, Ebbitt House, Washington, D. C. (18).
Cutting, Hiram A., M.D., State Geologist, Lunenburgh, Vt. (17).

Dall, Mrs. Caroline H., 141 Warren Avenue, Boston, Mass. (18).
Dall, Wm. H., care Smithsonian Institution, Washington, D. C. (18).
Dalrymple, Rev. Dr. E. A., Baltimore, Md. (11).
Dana, Edward Salisbury, New Haven, Conn. (23).
Dana, Prof. James D., New Haven, Conn. (1).
Danforth, Edward, Dep't of Public Instruction, Elmira, N. Y. (11).
Dawson, Dr. J. W., Principal McGill College, Montreal, Canada (10).
Day, F. H., M.D., Wauwatosa, Wis. (15).
Dean, George W., U. S. Coast Survey, Fall River, Mass. (20).
Dimmock, George, 19 Baldwin St., Cambridge, Mass. (22).
Dinwiddie, Robert, 113 Water St., New York (1).
Dodge, Charles R., Washington, D. C. (22).

Dutton, Capt. Clarence E., U. S. Ordnance Dep't, Washington, D. C. (23).
Dwyer, Dr. John, Hartford, Conn. (23).

Eaton, Prof. D. G., Packer Institute, Brooklyn, N. Y. (19).
Eddy, Prof. H. T., University of Cincinnati, Cincinnati, Ohio (24).
Eimbeck, Wm., U.S.C.S., Washington, D. C. (17).
Elliott, Ezekiel B., Statistical Bureau, Washington, D. C. (10).
Elsberg, Louis, M.D., 614 Fifth Avenue, New York (23).
Emerson, Prof. Benjamin K., Amherst, Mass. (19).
Emerson, Prof. C. F., Dartmouth College, Hanover, N. H. (22).
Emerson, George B., LL.D., 3 Pemberton Square, Boston, Mass. (1).
Emerton, James H., Salem, Mass. (18).
Engelmann, Dr. George, St. Louis, Mo. (1).
Ernst, Rev. Carl W., P. O. Box 671, Providence, R. I. (23).
Eustis, Prof. Henry L., Cambridge, Mass. (2).
Evans, Asher B., Principal Union School, Lockport, N. Y. (19).

Fairbanks, Rev. Henry, St. Johnsbury, Vt. (14).
Farlow, Dr. W. G., 6 Park Square, Boston, Mass. (20).
Farmer, Moses G., Torpedo Station, Newport, R. I. (9).
Ferrel, William, U. S. Coast Survey Office, Washington, D. C. (11).
Fitch, Edmund H., Secretary Toledo Soc. Nat. Sciences, Toledo, O. (23).
Fitch, Edward H., Ashtabula, Ohio (11).
Fitch, O. H., Ashtabula, Ohio (7).
Fontaine, Prof. Wm. M., Univ. of W. Va., Morgantown, W. Va. (25).
Foote, Dr. A. E., 1223 Belmont Avenue, Philadelphia, Pa. (21).
Freeman, H. C., Alto Pass, Union Co., Ill. (17).

Gardiner, Rev. Frederic, D.D., Middletown, Conn. (23).
Garland, Landon C., Chancellor Vanderbilt Univ., Nashville, Tenn. (25).
Garman, S. W., Museum Comp. Zoology, Cambridge, Mass. (20).
Genth, Prof. F. A., University of Pennsylvania, Philadelphia, Pa. (24).
Gilbert, G. K., P. O. Box 806, Washington, D. C. (18).
Gill, Prof. Theodore, Smithsonian Institution, Washington, D. C. (17).
Gillman, Henry, Waldo, Alachua Co., Fla. (24).
Gilman, Daniel C., President of the Johns Hopkins University, Baltimore, Md. (10).
Gleason, F. L., Manufacturer Iron and Steel, Middletown, Conn. (23).
Goessman, Prof. C. A., Mass. Agricultural College, Amherst, Mass. (18).
Goode, Prof. George Brown, Middletown, Conn. (22).
Grant, Mrs. Mary J., Brookfield, Conn. (23).
Gray, Prof. Asa, Botanic Gardens, Cambridge, Mass. (1).
Green, Dr. Traill, Easton, Pa. (1).
Grimes, J. Stanley, 165 Mason St., Milwaukee, Wis. (17).

Grinnan, A. G., Orange Court House, Va. (7).
Grote, Aug. R., Director of the Museum Buffalo Society Natural Sciences, Buffalo, N. Y. (22).
Guyot, Prof. Arnold, Princeton, N. J. (1).

Hadley, George, 1355 Main Street, Buffalo, N. Y. (6).
Hagen, Dr. Hermann A., Museum Comp. Zoology, Cambridge, Mass. (7).
Haldeman, Prof. S. S., Chickies, Pa. (1).
Hale, Dr. William H., Albany, N. Y. (19).
Hall, Prof. Asaph, U. S. Naval Observatory, Washington, D. C. (25).
Hall, Prof. James, Albany, N. Y. (1).
Hambly, John B., Portsmouth, R. I. (18).
Hamlin, Dr. A. C., Bangor, Me. (10).
Harrington, Prof. Mark W., Ann Arbor, Mich. (22).
Harrison, Dr. B. F., Wallingford, Conn. (11).
Hasbrouck, Prof. Isaac E., Rutger's College, New Brunswick, N. J. (23).
Haskins, Rev. David Greene, Cambridge, Mass. (25).
Hawes, George W., New Haven, Conn. (23).
Hawkins, Dr. B. Waterhouse, Geological Museum, New Jersey College, Princeton, N. J. (17).
Hawley, C. T., 2400 Spring Avenue, Milwaukee, Wis. (20).
Hedrick, B. S., Examiner U. S. Patent Office, Washington, D. C. (19).
Henshaw, Henry W., Office U. S. Engineers, Lock Box 93, Washington, D. C. (24).
Herrick, Mrs. Sophie B., Baltimore, Md. (23).
Hilgard, Prof. Eugene W., University of California, Berkeley, Cal. (11).
Hilgard, Prof. Julius E., U. S. Coast Survey, Washington, D. C. (4).
Hill, George W., Mathematician, Nyack Turnpike, N. Y. (23).
Hill, Rev. Dr. Thomas, 68 Deering St., Portland, Me. (3).
Hinrichs, Prof. Gustavus, State University, Iowa City, Iowa (17).
Hitchcock, Prof. Charles H., Hanover, N. H. (11).
Holden, Prof. Edward S., Naval Observatory, Washington, D. C. (23).
Horsford, Prof. E. N., Cambridge, Mass. (1).
Hosford, Charles E., Terre Haute, Ind. (20).
Hough, Franklin B., Lowville, N. Y. (4).
Hough, G. W. (15).
Hoy, Philo R., M.D., Racine, Wis. (17).
Hunt, George, Providence, R. I. (9).
Hunt, Dr. T. Sterry, St. James Hotel, Boston, Mass. (1).
Huntington, Prof. J. H., Hanover, N. H. (19).
Hyatt, Prof. Alpheus, Natural History Society, Boston, Mass. (18).
Hyatt, James, Staufordville, Dutchess Co., N. Y. (10).

Jenks, Elisha T., Middleborough, Mass. (22).
Jenks, Prof. J. W. P., Middleborough, Mass. (2).

Johnson, Prof. S. W., Sheffield Scientific School, New Haven, Conn. (22).
Johnston, Prof. John, Middletown, Conn. (1).
Julien, Alexis A., School of Mines, Columbia College, New York (24).

Kellogg, Justin, 259 River St., Troy, N. Y. (19).
Kerr, Prof. W. C., Raleigh, N. C. (10).
King, Robert, M.D., Kalamazoo, Mich. (21).
Kirkwood, Prof. Daniel, Bloomington, Ind. (7).

Lambert, Rev. Thomas R., D.D., Charlestown, Mass. (18).
Lambert, Dr. T. S., 449 West 21st St., New York (21).
Langley, Prof. John W., University of Michigan, Ann Arbor, Mich. (23).
Langley, Prof. S. P., Director of Observatory, Allegheny, Pa. (18).
Lattimore, Prof. S. A., University of Rochester, Rochester, N. Y. (15).
Lawrence, George N., 172 Pearl St., New York (7).
Laws, Samuel S., Columbia, Mo. (23).
Lea, Dr. Isaac, 1622 Locust St., Philadelphia, Pa. (1).
LeConte, Dr. John L., 1625 Spruce St., Philadelphia, Pa. (1).
Leeds, Prof. Albert R., Stevens Institute, Hoboken, N. J. (23).
Leonard, N. R., State University, Iowa City, Iowa (21).
Lesley, Prof. J. Peter, State Geol. of Pa., 1008 Clinton St., Phil., Pa. (2)
Levette, Gilbert M., Geologist, Indianapolis, Ind. (23).
Lindsley, Dr. J. B , Nashville, Tenn. (1).
Lintner, J. A., N. Y. State Museum of Nat. Hist., Albany, N. Y. (22).
Little, Prof. George, State Geologist of Georgia, Atlanta, Ga. (15).
Little, W. C., Albany, N. Y. (22).
Lockwood, Rev. Samuel, Freehold, N. J. (18).
Loomis, Prof. Elias, New Haven, Conn. (1).
Loughridge, Prof. R. H., Ass't State Geologist, Atlanta, Ga. (21).
Lovering, Prof. Joseph, Cambridge, Mass. (2).
Lupton, Prof. N. T., Vanderbilt University, Nashville, Tenn. (17).
Lyman, Prof. Chester S., New Haven, Conn. (4).
Lyman, Col. Theodore, Brookline, Mass. (23).
Lyon, Dr. Henry, 34 Monument Sq., Charlestown, Mass. (18).

Mallett, Prof. J. W., University of Virginia, Va. (25).
Malone, David R., M.D., Edinburg, Ind. (20).
Mann, B. Pickman, 19 Follen St., Cambridge, Mass. (22).
Marcy, Prof. Oliver, Evanston, Ill. (10).
Marsh, Prof. O. C., Yale College, New Haven, Conn. (15).
Mason, Otis T., Columbian University, Washington, D. C. (25).
Mayer, Prof. Alfred M., Stevens Inst. Technology, Hoboken, N. J. (19)
McClintock, Frank, West Union, Iowa (22).
McMurtrie, William, Dep't Agriculture, Washington, D. C. (22).

McRae, Hamilton S., Sup't of Schools, Muncie, Ind. (20).
Means, Rev. A., Oxford, Ga. (5).
Meehan, Thomas, Germantown, Pa. (17).
Mees, Carl Leo, Louisville, Ky. (24).
Meigs, Dr. James Aitken, 1408 Spruce St., Philadelphia, Pa. (12).
Mendenhall, Prof. T. C., Agric. and Mechanical Coll., Columbus, Ohio (20).
Mitchell, Miss Maria, Vassar College, Poughkeepsie, N. Y. (4).
Moore, Prof. James W., M. D., Lafayette College, Easton, Pa. (22).
Morgan, Hon. L. H., Rochester, N. Y. (10).
Morley, Prof. Edward W., Hudson, Ohio (18).
Morris, Rev. John G., Baltimore, Md. (12).
Morse, Prof. Edward S., Imperial Univ. of Tokio, Tokio, Japan (18).
Morton, Henry, Stevens Institute Technology, Hoboken, N. J. (18).
Munroe, Prof. Chas. E., U. S. Naval Academy, Annapolis, Md. (22).

Nason, Prof. H. B., Rensselaer Polytechnic Inst., Troy, N. Y. (13).
Nelson, Prof. Edward T., Delaware, Delaware Co., O. (24).
Newberry, Prof. J. S., Cleveland, Ohio, and Columbia Coll., New York (5).
Newcomb, Prof. Simon, U. S. Naval Observatory, Washington, D. C. (13).
Newton, Hubert A., New Haven, Conn. (6).
Nichols, Prof. W. R., Mass. Inst. Technology, Boston, Mass. (18).
Niles, Prof. W. H., Cambridge, Mass. (16).
Nipher, Prof. F. E., Washington University, St. Louis, Mo. (24).
Norton, Prof. W. A., New Haven, Conn. (6).

Oliver, Prof. James E., Cornell University, Ithaca, N. Y. (7).
Oliver, Miss Mary E., Cascadilla Hotel, Ithaca, N. Y. (20).
Orton, Prof. Edward, President Ohio Agricultural and Mechanical College, Columbus, Ohio (19).
Osborne, John W., 212 Delaware Ave., N. E., Washington, D. C. (22).
Osten Sacken, Baron R., Newport, R. I. (10).
Owen, Dr. Richard, Indiana State University, Bloomington, Ind. (20).

Paine, Cyrus F., Rochester, N. Y. (12).
Paine, Nathaniel, Worcester, Mass. (18).
Palfray, Hon. Charles W., Salem, Mass. (21).
Parkhurst, Henry M., Law Stenographer, 33 Park Row, New York (23).
Parry, Dr. Charles C., Davenport, Iowa (6).
Peckham, S. F., University of Minnesota, Minneapolis, Minn. (18).
Pedrick, Wm. R., Lawrence, Mass. (22).
Peirce, B. O., 413 Broadway, Cambridge, Mass. (18).
Perkins, Maurice, Schenectady, N. Y. (15).
Pettee, Prof. William H., Ann Arbor, Mich. (24).
Phippen, Geo. D., Salem, Mass. (18).
Pickering, Prof. Edw. C., Director of Observatory, Cambridge, Mass. (18).

Pourtales, L. F., Keeper Museum Comp. Zoology, Cambridge, Mass. (1).
Powell, Major J. W., 910 M St., Washington, D. C. (23).
Prescott, Prof. Albert B., Ann Arbor, Mich. (23).
Prime, Prof. Frederick, jr., Lafayette College, Easton, Pa. (24).
Pumpelly, Prof. Raphael, Owego, Tioga County, N. Y. (17).
Putnam, F. W., Curator Peabody Museum Archæology and Ethnology, Cambridge, Mass. Address as Permanent Secretary, A. A. A. S., Salem, Mass. (10).
Pynchon, Rev. Thomas R., Pres't of Trinity College, Hartford, Conn. (23).

Quimby, Prof. E. T., Hanover, N. H. (22).
Quincy, Edmund, 85 Clinton St., Boston, Mass. (11).

Raymond, Rossiter W., 17 Burling Slip, New York (15).
Redfield, John H., care A. Whitney and Sons, Philadelphia, Pa. (1).
Remsen, Prof. Ira, Cathedral St., Baltimore, Md. (22).
Rice, Prof. Wm. North, Middletown, Conn. (18).
Richards, Prof. Robert H., Mass. Inst. Tech., Boston, Mass. (22).
Riley, Prof. C. V., U. S. Entomologist, Washington, D. C. (17).
Ritchie, E. S., 150 Tremont St., Boston, Mass. (10).
Rockwell, Joseph P., Creston, Iowa (17).
Rockwood, Prof. Charles G., jr., Princeton, N. J. (20).
Roepper, Charles W., Bethlehem, Pa. (23).
Rogers, Fairman, 202 West Rittenhouse Square, Philadelphia, Pa. (11).
Rogers, Prof. Robert E., University of Penn., Philadelphia, Pa. (18).
Rogers, W. A., Ass't Harvard Coll. Observatory, Cambridge, Mass. (15).
Rogers, Prof. William B., 117 Marlborough St., Boston, Mass. (1).
Rood, Prof. O. N., New York (14).
Roosevelt, Clinton, 11 Wall St., New York (11).
Runkle, Prof. J. D., President Institute of Technology, Boston, Mass. (2).
Rutherford, Lewis M., 175 Second Ave., New York (13).

Sadtler, Prof. Samuel P., University of Penn., Philadelphia, Pa. (22).
Safford, Dr. James M., Nashville, Tenn. (6).
Saunders, William, London, Ontario, Canada (17).
Saville, Dr. John J., Sioux City, Iowa (22).
Schott, Charles A., Coast Survey Office, Washington, D. C. (8).
Schweitzer, Prof. Paul, State University of Mo., Columbia, Mo. (24).
Scudder, Samuel H., Cambridge, Mass. (13).
Seaman, Wm. H., Microscopist, Agric. Dep't, Washington, D. C. (23).
Shaler, Prof. N. S., Cambridge, Mass. (19).
Sias, Solomon, M.D., Schoharie, Schoharie Co., N. Y. (10).
Sill, Hon. Elisha N., Cuyahoga Falls, Ohio (6).
Silliman, Prof. Benjamin, Yale College, New Haven, Conn. (1).
Silliman, Prof. Justus M., Lafayette College, Easton, Pa. (19).

Smith, Prof. Eugene A., University of Alabama, Tuscaloosa, Ala. (20).
Smith, Dr. J. Lawrence, Louisville, Ky. (1).
Smith, Prof. S. I., Yale College, New Haven, Conn. (18).
Spencer, John W., Teacher and Geologist, Paxton, Sullivan Co., Ind. (20).
Stanard, Benjamin A., Cleveland, Ohio (6).
Stearns, Henry P., M.D., Hartford, Conn. (23).
Stearns, R. E. C., P. O. Box 13, Berkeley, Cal. (18).
Steiner, Dr. Lewis H., Frederick City, Md. (7).
Stephens, W. Hudson, Lowville, N. Y. (18). Life Member.
Stockwell, John N., 579 Case Avenue, Cleveland, Ohio (18).
Stone, Mrs. Leander, 1571 Indiana Avenue, Chicago, Ill. (22).
Stone, Ormond, Director Cincinnati Observatory, Univ. of Cincinnati, Mt. Lookout, Ohio (24).
Storrs, Henry E., Jacksonville, Ill. (20).
Stuart, Prof. A. P. S., Lincoln, Nebraska (21).
Swallow, Prof. G. C., Columbia, Mo. (10).

Tappan, Prof. Eli T., Kenyon College, Gambier, Ohio (20).
Terry, Prof. Nathaniel M., U. S. Naval Academy, Annapolis, Md. (23).
Thompson, A. Remsen, 50 West 51st Street, New York (1).
Thurston, Prof. Robert H., Stevens Institute, Hoboken, N. J. (23).
Toner, Joseph M., M.D., 615 Louisiana Ave., Washington, D. C. (23).
Trowbridge, Prof. John, Cambridge, Mass. (25).
Trowbridge, Prof. W. P., New Haven, Conn. (10).
Turnbull, Laurence, M.D., 1208 Spruce St., Philadelphia, Pa. (10).
Tuttle, Prof. Albert H., Columbus, Ohio (17).

Uhler, Philip R., Baltimore, Md. (19).

Van der Weyde, Dr. P. H., P. O. Box 4379, New York (17).
Van Vleck, Prof. John M., Middletown, Conn. (23).
Vaux, William S., 1702 Arch St., Philadelphia, Pa. (1). Life Member.
Verrill, Prof. A. E., Yale College, New Haven, Conn. (16).
Vose, Prof. George L., Bowdoin College, Brunswick, Me. (15).

Wadsworth, M. Edward, Assistant in Geology, Harvard University, 42 Langdon St., Cambridge, Mass. (23).
Walker, Prof. Joseph B., care Bank of Kentucky, Louisville, Ky. (20).
Walker, Prof. J. R., Napoleon Ave., cor. Coliseum St., New Orleans, La. (19).
Waller, Elwyn, School of Mines, Columbia College, New York (23).
Walling, H. F., 102 Chauncey St., Boston, Mass. (16).
Ward, Prof. Henry A., Rochester, N. Y. (13).
Ward, Henry D. A., Meteorologist, Middletown, Conn. (23).

Ward, Dr. R. H., 53 Fourth St., Troy, N. Y. (17).
Warner, James D., 199 Baltic St., Brooklyn, N. Y. (18). Life Member.
Warren, Gen. G. K., U. S. A., Engineer's Office, Newport, R. I. (12).
Warren, Prof. S. Edward, Newton, Mass. (17).
Watson, Sereno, Botanic Gardens, Cambridge, Mass. (22).
Webster, Prof. Nathan B., Principal Webster Inst., Norfolk, Va. (7).
Wells, Daniel H., Hartford, Conn. (18).
Westcott, O. S., Racine, Wis. (21).
Wheatland, Dr. Henry. President Essex Institute, Salem, Mass. (1).
Wheatley, Charles M., Phœnixville, Pa. (1).
Wheildon, W. W., Concord, Mass. (13).
White, Prof. C. A., P. O. Box 806, Washington, D. C. (17).
Whitfield, R. P., 173 Elm St., Albany, N. Y. (18).
Whitney, Solon F., Watertown, Mass. (20).
Whittlesey, Col. Charles, Cleveland, Ohio (1).
Wilbur, G. M., Pine Plains, N. Y. (19).
Wilbur, A. B., Port Jervis, Orange Co., N. Y. (23).
Wilder, Prof. Burt G., Cornell University, Ithaca, N. Y. (22).
Wiley, Prof. Harvey W., Purdue University, La Fayette, Ind. (21).
Williams, Charles H., M. D., 15 Arlington St., Boston, Mass. (22).
Williams, Prof. Henry W., 15 Arlington St., Boston, Mass. (11).
Wilson, Prof. Daniel, 117 Bloor St., Toronto, Canada (25).
Winchell, Prof. Alex., Ann Arbor, Mich. (3).
Winchell, Prof. N. H., University of Minnesota, Minneapolis, Minn. (19).
Witter, F. M., Muscatine, Iowa (21).
Worthen, A. H., Warsaw, Ill. (5).
Wright, Prof. Arthur W., Yale College, New Haven, Conn. (14).
Würtele, Rev. Louis C., Acton Vale, Province of Quebec, Canada East (11).
Wyckoff, Wm. C., Tribune Office, New York (20).
Wylie, Prof. Theophilus A., Indiana University, Bloomington, Ind. (20).

Yarrow, Dr. H. C., care Army Medical Museum, Washington, D. C. (23).
Youmans, Prof. Edward L., New York (6).
Young, C. A., Prof. of Astronomy, College of New Jersey, Princeton, New Jersey (18).

[356 FELLOWS.]

TOTAL NUMBER OF MEMBERS OF THE ASSOCIATION, 953.

MEMBERS ELECTED

AT

NASHVILLE MEETING.

Two hundred and nineteen members were elected at the Nashville Meeting. Of these one hundred and fifty-seven have paid the admission fee and assessments for the meeting, and their names have been incorporated in the list of Members. Seven have declined, one has died since the meeting, and the fifty-four following have not yet perfected their membership:

Andrews, George, Knoxville, Tenn.
Atchison, William A., Nashville, Tenn.
Beal, William, Murphy, N. C.
Beckett, Rev. George, Columbia, Tenn.
Blackman, A. L., Nashville, Tenn.
Chamberlain, H. S., Chattanooga, Tenn.
Charbonier, L. H., Athens, Ga.
Cheatham, William A., M. D., Nashville, Tenn.
Clingman, Gen. Thomas K., Asheville, N. C.
Cole, E. W., Nashville, Tenn.
Cornwall, George R.. E. M., Ducktown, Tenn.
Cross, George W., Franklin, Tenn.
Draper, Dr. Henry, New York.
Eaton, Lucien B., Memphis, Tenn.
Frisby, Prof. Edgar, Washington, D. C.
Glenn, Prof. William Frank, M. D., Nashville, Tenn.
Hambach, Dr. G.. St. Louis, Mo.
Hamby, William R., Nashville, Tenn.
Hilder, F. F., St. Louis, Mo.
Howell, Morton B., Nashville, Tenn.
James, Hon. Elbert A., Chattanooga, Tenn.
Jenney, Walter B., E. M., New York.
Jones, Edward S., Nashville, Tenn.
Kelley, David C., M. D., Nashville, Tenn.
Lindsley, Stuart, E. M., Ducktown, Tenn.
Martin, Rev. Carlisle P. B., College Station, Texas.

McConnell, John B., M. D., Nashville, Tenn.
McGavock, Jacob, Nashville, Tenn.
Menees, Prof. Thomas, Nashville, Tenn.
Michels, John, New York.
Moore, Gideon E., Ph. D., Jersey City, N. J.
Nichol, William L., M. D., Nashville, Tenn.
Peck, W. L., M. D., Indianapolis, Ind.
Porter, Hon. James D., Paris, Tenn.
Reese, Prof. William B., Nashville, Tenn.
Robertson, D. A., St. Paul, Minn.
Rodgers, Rear Admiral John, U. S. N., Washington, D. C.
Schley, William S., Atlanta, Ga.
Selden, Samuel, M. D., Norfolk, Va.
Shaler, Mrs. N. S., Cambridge, Mass.
Skinner, Aaron, Washington, D. C.
Sweeny, R. Ormsby, St. Paul, Minn.
Thach, Charles C., Hopkinsville, Ky.
Thornton, Prof. E. Q., Auburn, Ala.
Tichenor, Dr. J. E., Auburn, Ala.
Treat, Mrs. Mary B., Vineland, N. J.
Tutwiler, Miss Julia, Tuscaloosa, Ala.
Wells, James S. C., Ph. B., New York.
Wetherbee, Albert G., Cincinnati, O.
White, Prof. H. C., Athens, Ga.
Wight, Hon. E. M., M. D., Chattanooga, Tenn.
Williamson, George W., M. D., Nashville, Tenn.
Williston, S. W., New Haven, Conn.
Wright, B. F., St. Paul, Minn.

DECEASED MEMBERS.

[Information respecting omissions in this list, and the date of birth and of decease of any of the former members, is requested by the Permanent Secretary.]

Abbott, J. J., Washington, D. C. (1).
Adams, C. B., Amherst, Mass. (1).
Adams, Edwin F., Charlestown, Mass. (18).
Adams, Samuel, Jacksonville, Ill. (18).
Agassiz, Louis, Cambridge, Mass. (1).
Ainsworth, J. G., Barry, Mass. (14).
Allston, R. F. W., Georgetown, S. C. (3).
Anthony, Charles H., Albany, N. Y. (6).
Ames, N. P., Springfield, Mass. (1).
Appleton, Nathan, Boston, Mass. (1).
Bache, Alexander D., Washington, D. C. (1).
Bache, Franklin, Philadelphia, Pa. (1).
Bailey, J. W., West Point, N. Y. (1).
Barrett, Moses, Milwaukee, Wis. (21).
Beck, C. F., Philadelphia, Pa. (1).
Beck, Lewis C., New Brunswick, N. J. (1).
Beck, T. Romeyn, Albany, N. Y. (1).
Benedict, G. W., Burlington, Vt. (16).
Bicknell, Edwin, Boston, Mass. (18).
Binney, Amos, Boston, Mass. (1).
Binney, John, Boston, Mass. (3).
Blanding, William, R. I. (1).
Blatchford, Thomas W., Troy, N. Y. (6).
Blatchley, Miss S. L., New Haven, Conn. (19).
Bomford, George, Washington, D. C. (1).
Bradley, Leverette, Jersey City, N. J. (15).
Braithwaite, Jos., Chambly, C. W. (11).
Brown, Andrew, Natchez, Miss. (1).
Burnap, G. W., Baltimore, Md. (12).
Burnett, Waldo I., Boston, Mass. (1).
Butler, Thomas B., Norwalk, Conn. (10).
Carpenter, Thornton, Camden, S. C. (7).
Carpenter, William M., New Orleans, La. (1).
Case, William, Cleveland, Ohio (6).
Caswell, Alexis, Providence, R. I. (2).
Chapman, N., Philadelphia, Pa. (1).
Chase, S., Dartmouth, N. H. (2).
Chauvenet, William, St. Louis, Mo. (1).
Clapp, Asahel, New Albany, Ind. (1).
Clark, H. J., Cambridge, Mass. (13).
Clark, Joseph, Cincinnati, Ohio (5).
Clarke, A. B., Holyoke, Mass. (13).
Cleaveland, C. H., Cincinnati, Ohio (9).
Cleveland, A. B., Cambridge, Mass. (2).
Coffin, James H., Easton, Pa. (1).
Cole, Thomas, Salem, Mass. (1).
Coleman, Henry, Boston, Mass. (1).

Conrad, A. Timothy, Philadelphia, Pa. **(1).**
Cooper, William, Hoboken, N. J. (9).
Corning, Erastus, Albany, N. Y. (6).
Couper, J. Hamilton, Darien, Ga. (1).
Crosby, Alpheus, Salem, Mass. (10).
Crosby, Thomas R., Hanover, N. H. (18).
Croswell, Edwin, Albany, N. Y. (6).
Curry, W. F., Geneva, N. Y. (11).
Dayton, Edwin A., Madrid, N. Y. (7).
Dean, Amos, Albany, N. Y. (6).
Dearborn, George H. A. S., Roxbury, Mass. **(1).**
Dekay, James E., New York (1).
DeLaski, John, Carver's Harbor, Me. (18).
Dewey, Chester, Rochester, N. Y. (1).
Dexter, G. M., Boston, Mass. (11).
Dillingham, W. A. P., Augusta, Me. (17).
Doggett, Wm. E., Chicago, Ill. (17).
Doolittle, L., Lenoxville, C. E. (11).
Ducatel, J. T., Baltimore, Md. (1).
Duffield, George, Detroit, Mich. (10).
Dumont, A. H., Newport, R. I. (14).
Duncan, Lucius C., New Orleans, La. (10).
Dunn, R. P., Providence, R. I. (14).
Easton, Norman, Fall River, Mass. (14).
Eaton, James H., Beloit, Wis. (17).
Ely, Charles Arthur, Elyria, Ohio (4).
Emmons, Ebenezer, Williamstown, Mass. **(1).**
Engstrom, A. B., Burlington, N. J. (1).
Everett, Edward, Boston, Mass. (2).
Ewing, Thomas, Lancaster, Ohio (5).
Ferris, Isaac, New York (6).
Feuchtwanger, Lewis, New York (11).
Fillmore, Millard, Buffalo, N. Y. (7).
Fisher, Mark, Trenton, N. J. (10).
Fitch, Alexander, Hartford, Conn. (1).
Forbush, E. B., Buffalo, N. Y. (15).
Force, Peter, Washington, D. C. (4).
Foster, J. W., Hyde Park, Chicago, Ill. **(1).**
Foucon, Felix, Madison, Wis. (18).
Fowle, Wm. B., Boston, Mass. (1).
Fox, Charles, Grosse Ile, Mich. (7).
Frazer, John F., Philadelphia, Pa. (1).
French, J. W., West Point, N. Y. **(11).**
Gavit, John E., New York (1).
Gay, Martin, Boston, Mass. (1).
Gibbon, J. H., Charlotte, N. C. (3).
Gillespie, W. M., Schenectady, N. Y. (10).
Gilmor, Robert, Baltimore, Md. (1).
Gould, Augustus A., Boston, Mass. (11).
Gould, B. A., Boston, Mass. (2).
Graham, James D., Washington, D. C. **(1).**
Gray, Alonzo, Brooklyn, N. Y. (13).
Gray, James H., Springfield, Mass. (6).
Greene, Benjamin D., Boston, Mass. (1).
Greene, Everett W., Madison, N. J. (10).
Greene, Samuel, Woonsocket, R. I. (9).
Greer, James Dayton, Ohio (20).
Griffith, Robert E., Philadelphia, Pa. (1).
Griswold, John A., Troy, N. Y. (19).

Guest, William E., Ogdensburg, N.Y. (6).
Hackley, Charles W., New York (4).
Hale, Enoch, Boston, Mass. (1).
Hance, Ebenezer, Fallsington P. O., Pa. (7).
Hare, Robert, Philladelphia, Pa. (11).
Harlan, Joseph G., Haverford, Pa. (8).
Harlan, Richard, Philladelphia, Pa. (1).
Harris, Thaddeus W., Cambridge, Mass. (1).
Harrison, Jos., jr., Philadelphia, Pa. (12).
Hart, Simeon, Farmington, Conn. (1).
Hartt, Charles F., Ithaca, N. Y. (18).
Haven, Joseph, Chicago, Ill. (17).
Hayden, H. H., Baltimore, Md. (1).
Hayward, James, Boston, Mass. (1).
Henry, Joseph, Washington, D. C. (1).
Hilgard, Theo. C., St. Louis, Mo. (17).
Hickox, S. V. R., Chicago, Ill. (17).
Hincks, William, Toronto, C. W. (11).
Hitchcock, Edward, Amherst, Mass. (1).
Hodgson, W. B., Savannah, Ga. (10).
Holbrook, J. E., Charleston, S. C. (1).
Hopkins, Albert, Williamstown, Mass. (19).
Hopkins, James G., Ogdensburg, N. Y. (10).
Hopkins, T. O., Williamsville, N. Y. (10).
Hosford, Benj. F., Haverhill, Mass. (13).
Horton, C. V. R , Chaumont, N. Y. (10).
Horton, William, Craigville, Orange Co., N. Y. (1).
Houghton, Douglas, Detroit, Mich. (1).
Hovey, Edmund O., Crawfordsville, Ind. (20).
Howland, Theodore, Buffalo, N. Y. (15).
Hubbert, James, Richmond, Province of Quebec (16).
Hunt, E. B., Washington, D. C. (2).
Hunt, Freeman, New York (11).
Ives, Moses B., Providence, R. I. (9).
Ives, Thomas P., Providence, R. I. (10).
Johnson, W. R., Washington, D. C. (1).
Jones, Catesby A. R., Washington, D. C. (8).
Keep, N. C., Boston, Mass. (13).
Kennicott, Robert, West Northfield, Ill. (12).
King, Mitchell, Charleston, S. C. (3).
Knickerbocker, Charles, Chicago, Ill. (17).
Lacklan, R., Cincinnati, Ohio (11).
Lapham, Increase A., Milwaukee, Wis. (3).
LaRoche, R., Philadelphia, Pa. (12).
Lasel, Edward, Williamstown, Mass. (1).
Lawford, Frederick, Montreal, Canada (11).
Lederer, Baron von, Washington, D. C. (1).
Lieber, Oscar M., Columbia, S. C. (8).
Lincklaen, Ledyard, Cazenovia, N. Y. (1).
Linsley, James H., Stafford, Conn. (1).
Lockwood, Moses B., Providence, R. I. (9).
Logan, William E., Montreal, Canada (1).
Loosey, Charles F., New York (12).
Lothrop, Joshua R., Buffalo, N. Y. (15).
Lyon, Sidney S., Jeffersonville, Ind. (20).
Maack, G. A., Cambridge, Mass. (18).
Mahan, D. H., West Point, N. Y. (9).
Marsh, Dexter, Greenfield, Mass. (1).
Marsh, James E., Roxbury, Mass. (10).

Mather, William W., Columbus, Ohio (1).
Maupin, S., Charlottesville, Va. (10).
McMahon, Mathew, Albany, N. Y. (11).
M'Conihe, Isaac, Troy, N. Y. (5).
Meade, George G., Philadelphia, Pa. (15).
Meek, F. B., Washington, D. C. (6).
Mitchell, O. M., Cincinnati, Ohio (3).
Mitchell, William, Poughkeepsie, N. Y. (3).
Mitchell, Wm. H., Florence, Ala. (17).
Morton, S. G., Philadelphia, Pa. (1).
Munroe, Nathan, Bradford, Mass. (6).
Munroe, William, Concord, Mass. (18).
Newton, E. H., Cambridge, N. Y. (1).
Nicollett, J. N., Washington, D. C. (1).
Norton, J. P., New Haven, Conn. (1).
Noyes, J. O., New Orleans, La. (21).
Nutt, Cyrus, Bloomington, Ind. (20).
Oakes, William, Ipswich, Mass. (1).
Ogden, William B., High Bridge, Westchester Co., N. Y. (17).
Olmsted, Alexander F., New Haven, Conn. (4).
Olmsted, Denison, New Haven, Conn. (1).
Olmsted, Denison, jr., New Haven, Conn. (1).
Painter, Jacob, Lima, Pa. (23).
Painter, Minshall, Lima, Pa. (7).
Parker, Wilbur F., West Meriden, Conn. (23).
Parkman, Samuel, Boston, Mass. (1).
Perkins, George R., Utica, N. Y. (1).
Perkins, Henry C., Newburyport, Mass. (18).
Perry, John B., Cambridge, Mass. (16).
Perry, M. C., New York (10).
Piggot, A. Snowden, Baltimore, Md. (10).
Plumb, Ovid, Salisbury, Conn. (9).
Pope, Charles A., St. Louis, Mo. (12).
Porter, John A., New Haven, Conn. (14).
Pugh, Evan, Centre Co., Penn. (14).
Read, Ezra, Terre Haute, Ind. (20).
Redfield, William C., New York (1).
Resor, Jacob, Cincinnati, Ohio (8).
Robb, James, Fredericton, N. B. (4).
Robinson, Coleman T., Buffalo, N. Y. (15).
Rockwell, John A., Norwich, Conn. (10).
Rogers, Henry D., Glasgow, Scotland (1).
Rogers, James B., Philadelphia, Pa. (1).
Sager, Abram, Ann Arbor, Mich. (6).
Schaeffer, Geo. C., Washington, D. C. (1).
Scott, Joseph, Dunham, C. E. (11).
Senter, Harvey S., Aledo, Ill. (20).
Seward, William H., Auburn, N. Y. (1).
Sherwin, Thomas, Dedham, Mass. (11).
Silliman, Benjamin, New Haven, Conn. (1).
Skinner, John B., Buffalo, N. Y. (15).
Slack, J. H., Philadelphia, Pa. (12).
Smith, James Y., Providence, R. I. (9).
Smith, J. V., Cincinnati, Ohio (5).
Smith, Lyndon A., Newark, N. J. (9).
Snell, Ebenezer S., Amherst, Mass. (2).
Sparks, Jared, Cambridge, Mass. (2).
Stimpson, William, Chicago, Ill. (12).
Stone, Samuel, Chicago, Ill. (17).

of such collections, in accordance with a previously arranged plan, could not fail to lead to important results for geological science. The INTERNATIONAL EXHIBITION to be held at Paris in 1878 will furnish such an occasion, and it is proposed to invite to that end governmental geological surveys, learned societies and private individuals throughout the world, to send to Paris such collections as will make the geological department of that exhibition as complete as possible.

In order to take advantage of the collections which may thus be brought together it is moreover proposed to convoke an INTERNATIONAL GEOLOGICAL CONGRESS, to be held at Paris at some time during the Exhibition of 1878, and to make that Congress an occasion for considering many disputed problems in Geology.

In accordance with this plan it is proposed that the Geological department of the International Exhibition of 1878 shall embrace:

I. Collections of crystalline rocks, both crystalline schists and massive or eruptive rocks, including the so-called contact-formations and the results of the local alteration of uncrystalline sediments by eruptive masses. In this connection are to be desired all examples of organic remains found in crystalline rocks, including Eozoon and related forms. These collections should moreover comprehend all rare and unusual rocks of special lithological, mineralogical and chemical interest, examples of ore-deposits and of veinstones of all kinds, with their encasing rocks. As far as possible these collections should be limited to specimens of a size convenient for examination, and be accompanied with sections prepared for microscopic study. In the arrangement of all these materials regard should be had to their natural associations rather than to theoretical notions or artificial classifications, so that they may be studied not only petrographically but geognostically.

II. Collections illustrating the fauna and the flora of the palæozoic and more recent periods, particularly of such horizons as present a more critical interest to palæontologists from the first appearance or the disappearance of important groups of organic forms. It has appeared to the Committee named below that the organic remains of the Cambrian, Taconic or so-called Primordial strata merit especial attention in this connection.

These various collections should be explained as fully as possible by labels, catalogues, monographs and maps.

III. Collections of geological maps, and also of sections and models, especially such as serve to illustrate the laws of mountain-structure. In the geological maps regard should be had to various questions which deserve the special consideration of the Congress, such as the scales best adapted for different purposes, the colors and symbols to be used, and the proper mode of representing superficial deposits conjointly with the underlying formations. A discussion of these will prepare the way for improved general geological maps of the continents.

In pursuance of the above plan the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE during its annual meeting at Buffalo, under the presidence of Prof. William B. Rogers, unanimously adopted the following resolution on the 25th of August, 1876.

> *Resolved*, that a Committee of the Association be appointed by the Chair to consider the propriety of holding an International Congress of Geologists at Paris during the International Exhibition in 1878, for the purpose of getting together comparative collections, maps and sections, and for the settling of many obscure points relating to geological classification and nomenclature. And that to this Committee be added our guests, Prof. T. H. Huxley of England, Dr. Otto Torell of Sweden, and Dr. E. H. von Baumhauer of the Netherlands, who shall be requested to open negotiations in Europe looking to a full representation of European geologists at the proposed Congress. The said Committee to consist of Prof. William B. Rogers, Messrs. James Hall, J. W. Dawson, J. S. Newberry, T. Sterry Hunt, C. H. Hitchcock and R. Pumpelly in behalf of the Association, with the addition of Prof. T. H. Huxley, Dr. Otto Torell and Dr. E. H. von Baumhauer.

On the same day, at a meeting of the Committee, Prof. James Hall was elected Chairman, and Dr. T. Sterry Hunt, Secretary. It was then resolved to prepare the present circular, to be printed in English, French and German, and distributed to geologists throughout the world, asking their coöperation in this great work of an INTERNATIONAL GEOLOGICAL EXHIBITION and an INTERNATIONAL GEOLOGICAL CONGRESS to be held at Paris in 1878; the precise date of the Congress to be subsequently fixed.

All those interested in this project are invited to communicate with any one of the following members of the Committee:—

PROF. T. H. HUXLEY, LONDON, ENGLAND,
DR. OTTO TORELL, STOCKHOLM, SWEDEN,
DR. E. H. VON BAUMHAUER, HARLEM, HOLLAND,
DR. T. STERRY HUNT, BOSTON, MASS., U. S. A.

BOSTON, MASSACHUSETTS, Sept., 1876.

The circular and translations of it into French and German were printed, and before the end of the last year had been sent by the Secretary to the principal scientific societies and academies, as well as to the workers in geology throughout the world. The response to this invitation has been most gratifying. The Geological Society of France has formally recognized the great importance of the objects proposed, and promised its hearty coöperation, while private letters from its President to the Secretary of the Committee, and from Prof. Hébert to Prof. Hall, give cordial assurances of the same kind. Spanish and Italian geologists have translated and published the circular in their respective languages, and have communicated to the Secretary their hearty approval of

the plan. Prof. Capellini has, in this connection, published an interesting correspondence, calling attention to the fact that in 1871 he had laid the project of a similar International Geological Congress, to be held in Italy, before the Italian Minister of Agriculture, Industry and Commerce.

The Geological Society of London, and the Geological Survey of Great Britain, have also formally signified their approval of our objects, and the coöperation of Norway, Sweden, Russia and Austria-Hungary is promised. It is to be regretted that Germany has declined to take a part in the International Exhibition of 1878, but we trust that this will not prevent her geologists from joining in the proposed Congress. The director of the Geological Survey of Japan promises to aid in our work, and we have the same assurance from Brazil, where the circular has been translated into Portuguese. Chili and Mexico have also responded, and promise an ample representation of their geology at Paris next year, while Canada, both through her Geological Survey and in the person of Dr. Dawson, will probably be represented there.

The Government of the United States has as yet failed to accept the invitation of France to take a part in the Exhibition of 1878, so that American geologists are not certain that they will be able to participate in the International Geological Exhibition. We are, however, assured that the Government is very desirous to have our country duly represented at Paris; and it is to be hoped that at the approaching extra session of the Congress of the United States measures will be taken for accepting the French invitation, and for appointing a commission, so that our people may secure a representation in Paris. I am assured, on all sides, that our geologists desire to contribute largely to the International Geological Exhibition, and even at this late day it will be possible to do much. In any event, it is probable that several members of our Committee will be present at the proposed Geological Congress. The precise date of this has not yet been fixed, though your Secretary is now in correspondence with the Secretary of the Geological Society of France upon this point, and believes that with the coöperation of that body a time convenient to all will be agreed upon.

It is recommended by the Standing Committee of the Association that in addition to the names of Prof. J. P. Lesley, of Philadelphia, and Prof. A. C. Ramsay, director of the Geological

Survey of Great Britain (already added to the International Committee), the Presidents, for the time being, of the Geological Societies of France, London, Edinburgh and Dublin, of Berlin, of Belgium, Italy, Spain, Portugal, and the Imperial Geological Institute of Vienna be invited to form a part of our commission.

Respectfully submitted on behalf of the Committee,

T. Sterry Hunt, *Secretary*.

Note.—Shortly after the presentation of the above report the Secretary received official notice that the Geological Society of France had, in coöperation with the above plan, appointed at Paris a local committee of organization for the proposed Congress, constituted as follows:—Hébert, president; Tournouer and Albert Gaudry, vice-presidents; Bioche, treasurer; Jannetaz, secretary-general; Delaire, Sauvage, Brocchi and Vélain, secretaries; with the following,—Belgrand, Bureau, de Chancourtois, G. Cotteau, Damour, Daubrée, Delafosse, Delesse, Descloizeaux, Desnoyers, Fruqué, V. Gervais, Gruner, De Lapparent, Mallard, Milne-Edwards, Pellat, the Marquis de Roys and L. Vaillant,—members of the Committee. To these they propose to add, with the title of foreign members, the names of the International Committee.

A circular issued by this Committee, bearing date July 31, invites all those interested in geological, mineralogical and paleontological studies, to take part in the approaching Congress, and to subscribe the sum of *twelve francs* each, which will give a card of admission to the Congress, and right to all the publications thereof. All those who intend to be present are at the same time invited to send, as soon as possible, a list of the questions which seem to them worthy of general discussion, as well as of the communications which they propose to make touching these questions. They are also invited to indicate the date which appears to them the most convenient for the meeting of the Congress.

As regards an International Geological Exhibition, the Paris committee of organization state that the difficulty of finding a suitable locality seems to them an obstacle in the way of realizing this part of the programme. They hope, however, that there will be many special collections sent, and beg the exhibitors of such,

to give the Committee due notice of these, in order that a special catalogue of them may be prepared.

The Secretary of the International Committee desires, in this connection, to call attention to the fact that his circular did not contemplate the holding of an International Geological Exhibition apart from the Universal Exhibition but, in the language of that circular, *the making as complete as possible the geological department of the Universal Exhibition.* It is certain that, as at all previous similar exhibitions, the different nations will contribute more or less of geological material, and it was conceived that such collections, extended and systematized in accordance with the plan set forth in the circular, would, while forming a part of the Universal exhibition, without farther cost, meet all the requirements of an International Geological Exhibition. To the accomplishment of this end, it will only be necessary for the exhibitors of all nations to send a list of their geological contributions to the local committee of organization at Paris.

All correspondence relating to the Congress should be addressed to *Dr. Jannetaz, secrétaire-général, rue des Grands-Augustins*, 7, *Paris, France;* and all moneys sent to *Dr. Bioche*, at the same address.

T. S. H.

Report of the Committee on Zoological Nomenclature to Section B, of the American Association for the Advancement of Science, at the Nashville Meeting, August 31, 1877.[1]

The undersigned was appointed at the last meeting a committee of one, to obtain an expression of opinion from the working naturalists of America, in regard to the nature of a set of rules for facilitating the decision of questions relating to nomenclature, and which might be adopted or recommended by the Section.

In accordance with the understanding and resolutions of the Section, by which this duty devolved upon him, your Reporter prepared a circular which was printed under the supervision of the Permanent Secretary and circulated by the Smithsonian Institution, a copy of which is appended to this report.

The recently published "Naturalists' Directory" afforded the addresses of nearly all the publishing naturalists, in the discrimination of whom valuable aid was received from Messrs. Scudder and LeConte.

The circular was sent to all who, within the last five years, might be included under the designation of publishing naturalists, and of whom the address could be obtained. This list included about eighty-five names, from a number of which (for various reasons), a response was hardly anticipated. They were used, however, in order that the fullest opportunity might be afforded to all those who might desire to express an opinion.

The responses received to date (Aug. 14, 1877), are forty-five in number. While a few honored names, to whose views all would attribute due weight, are not on the list, yet it includes most of those whose contributions are familiar in the Proceedings of Amer-

[1]By vote of the Section this report was referred to the Standing Committee, who directed that the report be printed and further action upon it deferred until the next meeting of the Association.

ican Scientific Societies, and an unquestionable majority of the best working naturalists of the country. The views of several of those from whom no response was received have been incorporated in the appendix by means of citations from their works.

The queries contained in the circular relate chiefly to certain points, concerning which a diversity of opinion has existed among naturalists; the general principles of nomenclature not being in question. The responses are divided into affirmative, negative and doubtful, while in individual cases some queries received no response. The answers classed as doubtful comprise those which, by their tenor, indicated that the purport of the particular query had not been clearly understood, and some in which the person replying avowed his inability to express a preference for any one of several modes of proceeding.

The gratifying unanimity which is exhibited, in the responses to certain of the more important and clearly defined questions at issue, indicates that a thorough study of the more complicated questions by the light of the general principles of nomenclature would result in a practical agreement on the part of American naturalists in relation to nearly all the matters in debate.

It is evident from the responses of naturalists, that their opinion is generally adverse to any attempt to limit, by arbitrary rules, the right of publication in the most convenient direction, and against any statute of limitations in regard to scientific names. This seems to be in accord with the principles of justice, equity and general usage in nomenclature, though at times inconvenient in its results. It may be confidently expected that the majority of authors, when their attention has been drawn to it will, for their own interests as well as that of science, avoid in future publications, the methods (or want of method), which in the remote past sowed so many germs of present difficulty.

It was thought by your Reporter that the best interests of science would be served, and the whole question be more clearly presented for future decision, by preparing such an appendix as that which forms the chief bulk of this report as now submitted.

This appendix consists of a résumé of all the principles and rules of nomenclature as heretofore set forth by the chief authorities on that subject, with the diverse views of different authors concerning each proposition appended to it and authenticated by their initials according to the accompanying list. In most cases,

a statement of the bearing of the responses to the circular upon each rule is included in the discussion following the rule. There are also some comments for which the writer is responsible.

A serious mistake appears to have been committed at the outset by divorcing Zoological from Botanical nomenclature, as was done by the committee of the British Association. The signal success which has attended the efforts of botanists to unify their nomenclature, when compared with the confusion reigning in some departments of zoology, is sufficient proof of this. Your Reporter, therefore, has endeavored to combine both in a symmetrical manner in one general whole. The principles and almost all the details are essentially identical in both. In performing this labor great dependence has been placed on the admirable memoir of De Candolle, and the writer is indebted to Dr. Asa Gray for kind suggestions in regard to doubtful points.

The rules and examples for the proper construction of compounds and derivatives from classical roots, for properly latinizing vernacular terms, and the table of equivalent letters in Greek and Latin have been amplified beyond the extent previously attempted by any writer on nomenclature, and also submitted for criticism to a competent professor of languages to insure accuracy. It is believed that this feature will prove useful to those naturalists not especially familiar with the classical languages.

While it has seemed necessary to criticise, in one or two matters of detail, the rules put forward by the two committees of the British Association, yet the wisdom and advisability of their recommendations in general must be fully conceded.

While the forms of expression, used by authors cited, have been frequently somewhat modified in translation or for harmony of diction, great care has been taken not in any way to modify the opinions expressed by each writer. For the Reporter's comments he is of course solely responsible. The few suggestions which he has ventured to make are open to free criticism; from which and from a study of the broad principles underlying the whole subject, a more satisfactory understanding on the matters in controversy can hardly fail to come about.

It will be readily understood that the labor involved in the preparation of this paper has not been slight, yet it seemed that in no other way could the matters concerned be brought before those interested in a satisfactory and impartial manner.

This report does not form a proposition to be acted on by the Section, or by the Association in a final manner at the present time. It is merely an attempt at a complete presentation of the subject, without which no well advised action by naturalists as a body can be expected or is to be desired. So far as is known to the Reporter, no such compilation has hitherto been attempted in modern times.

Many of the difficulties with which authors are confronted are the result of efforts by specialists to remedy confusion in their particular departments without reflection on the general bearing of the usages which they have attempted to introduce.

When free discussion, assisted by the light which this report may tend to throw upon nomenclature, shall have tested the opinions expressed and the reforms which have here and elsewhere been suggested, a fit time will have arrived to consider a more concise and definite code of rules and the subject of their recommendation by the Section. For the present this Report with its appendices is respectfully submitted.

Wm. H. Dall,
Committee.

APPENDIX.

CONTENTS.

PAGE.
13. Circular.
16. Schedule of replies to circular.
20. List of naturalists responding.
21. List of works subsequently referred to.
23. Discussion of the subject of nomenclature.
23. General Principles. § I-VII.
24. On the subordination and designation of groups belonging to the first category. § VIII-XI.
25. On the manner of designating particular groups, or those belonging to the second category. § XII-XVIII.
25. A. Denomination of the higher groups, or those of greater value than families or botanical orders. § XV.
26. B. Of Botanical families or orders. § XVI.
26. C. Of Zoological families, subfamilies and tribes. § XVII.
27. Permanency of names of the higher rank. § XIX.
27. Of names of genera and subdivisions of genera of higher rank than species. XX-XXV.
31. Of specific names and names of subdivisions of species. § XXVI-XXXI.
33. Of names of hybrids, sports and cultivated varieties used in botany. § XXXII-XXXIV.
34. Of the publication of names and the date to be assigned to each name or combination of names. § XXXV-XLIII.
36. Of the precision to be given to names by the citation of the author who first published them. § XLIV-XLIX.
39. Of names to be preserved in uniting, dividing or modifying the limits of existing groups. § L-LVII.
41. Of a starting point for binomial nomenclature. § LVIII, LIX.
44. Of synonyms and works subject to citation. § LX-LXIV.
48. Of names to be rejected, changed or modified. § LXV-LXVIII.
51. Of changes of names. § LXIX-LXXXI.
54. Of the names of organisms in modern languages. LXXXII.
55. Of the latinization of names. § LXXXIII.

CIRCULAR.

SMITHSONIAN INSTITUTION, WASHINGTON, D. C.,
February 1, 1877.

DEAR SIR:

AT the Buffalo meeting of the American Association for the Advancement of Science, 1876, a report from the Committee on Zoological Nomenclature was presented by the Chairman, Dr. LeConte, and after discussion it was decided that the undersigned be appointed a committee of one for the purpose of obtaining an expression of opinion from the working naturalists of the United States and Canada, in regard to the nature of a set of rules for facilitating the decision of questions relating to nomenclature, and which might be adopted and recommended by the Association. For this purpose it was decided to issue circulars. It was further understood that these circulars should be prepared, distributed, and, upon their return, a report upon the result prepared by the undersigned, to be presented at the Nashville meeting in 1877; these proceedings to be preliminary to consideration of, and definite action on the subject by the Association, if action be decided to be desirable.

In order to place some reasonable limit on the number to be distributed, it was decided that the circular should be sent only to those naturalists who have, during the last five years published descriptive zoological or botanical papers.

The question under consideration being one in which every naturalist must be more or less concerned, it is confidently expected that the persons who may receive the circular, will devote to it the small amount of time required to fulfil its purpose, in order that a full expression of opinion may be obtained. In order that as little writing as possible shall be required, the questions have been so framed as in most cases to call for only a categorical answer. This method is also absolutely essential to prevent ambiguity.

You are, therefore, requested to insert in the spaces left for the purpose in the accompanying circular, such answers to the questions of which it is composed, as are in your opinion most desirable and expedient. Having done this, you are further requested to sign and mail the circular to the undersigned as promptly as possible, in order that the preparation of the report may not be delayed.

I remain very respectfully,

WM. H. DALL,
Commit'ee.

NOTE.

The questions with which the working Naturalist is most frequently brought face to face — and in the decision of which so much trouble is experienced and such diverse opinions are elicited — are chiefly those which involve the right of any one of several names to be considered as properly proposed and entitled to take precedence of others, provided its priority in time of application be established.

The rule that names (otherwise unexceptionable) which are prior in date, are to be accepted in nomenclature to the exclusion of all others, is conceded by all naturalists.

The rules recommended by the Committee on Nomenclature of the British Association for the Advancement of Science, have been generally adopted: though in certain details they are regarded by many naturalists as defective. Nevertheless they have largely contributed to that uniformity which is so desirable in the matter of nomenclature.

It has been thought that a similar recommendation on the part of the American Association might reach many who are not conversant with the British rules and tend to produce in the works of the rising generation of American Naturalists a similarly beneficial agreement.

The differences of opinion which have arisen are chiefly in matters of detail and intrinsically of very slight importance.

One of the most serious in its effect upon nomenclature is that in regard to what names shall be considered as really binomial; another as to what is necessary to definitely establish a name in order that if prior to any other it may be accepted as properly proposed; and most of all as to the date to be adopted as that of the beginning of binomial nomenclature. This latter question, as to facts, on the authority of De Candolle, stands as follows:

A series of rules for nomenclature was to some extent foreshadowed by Linnæus in his *Fundamenta Entomologia* of 1736. These rules were first definitely proposed in the *Philosophia botanica*, which appeared in 1751. These rules, however, related almost exclusively to the generic name or *nomen genericum*. In 1745, he had employed for the first time a specific name (*nomen triviale*) composed of one word, in contradistinction to the polynomial designation of a species (*nomen specificum*) which was previously the rule among naturalists. That which now seems the most happy and important of the Linnæan ideas, the restriction of the specific name as now understood, seems to have been for a long time only an accessory matter to him, as the *nomina trivialia* are barely mentioned in his rules up to 1765.

In 1753, in the *Incrementa botanices*, while expatiating on the reforms which he had introduced into the science, he does not even mention the binominal nomenclature. In the *Systema Naturæ*, Ed. X, 1758, for the first time the binomial system is consistently applied to all classes of animals and plants (though it had been partially adopted by him as early

as 1745), and hence many naturalists have regarded the tenth edition as forming the most natural starting point. The system being of slow and intermittent growth, even with its originator, an arbitrary starting point is necessary. In the twelfth edition (1766–68), numerous changes and reforms were instituted, and a number of his earlier specific names were arbitrarily changed. In fact, Linnæus never seems to have regarded specific names as subject to his rules.

The last was recommended by the British Committee as the starting point. They have since, however, receded to the extent of admitting to recognition some ichthyological works printed between the dates of the tenth and twelfth editions.

QUESTIONS TO WHICH AN ANSWER IS DESIRED.

I. What date shall be taken as the commencement of the binomial era in nomenclature? For Ed. X, 18. Ed. XII, 17. 1736, 1. Botanists, 1753, 2. No answer, 7.

II. Shall phrases composed of two words which may appear in the publications of naturalists whose works preceded, or who did not in such works adopt the binomial system of nomenclature, be considered as binomial names? No, 32. Yes, 5. No answer or doubtful, 8.

III. If so, shall the first word of the said phrase be entitled to recognition as a generic name? No, 32. Yes, 5. No answer or doubtful, 8.

IV. If an author has not indicated his adoption of the binomial system by discarding all polynomial names in a given work, are any of his names therein entitled to recognition otherwise than in bibliography? No, 18. Yes, 18. Doubtful, 4. No answer, 5.

Example. Da Costa, in his work on the Conchology of Great Britain, varies from binomial to polynomial in his designations of species, and some of his "generic" names contain two or three words, while others apparently conform to the Linnæan system. Should any of these names be retained?

V. Does the reading of a paper before a scientific body constitute a publication of the descriptions or names of animals or plants contained therein? No, 39. Doubtful, 2. Yes, 4.

VI. Is a name in the vernacular of the publishing author, or a vernacular rendering from a classical root unaccompanied by a Latin or Greek form of the name, entitled to recognition except in bibliography? No, 36. Doubtful, 2. Yes, 4. No answer, 3.

VII. Is a name applied to a group of species, without a specification of any character possessed by them in common (that is, without any so-called generic diagnosis or description), entitled to recognition as an established generic name by subsequent authors? No, 38. Doubtful, 3. Yes, 3. No answer, 1.

VIII. Is a generic name applied to a single (then or previously) described species without a generic diagnosis or description of any kind, entitled to recognition as above, by subsequent authors? No, 37. Doubtful, 3. Yes, 4. No answer, 1.

IX. Is a name, when used in a generic sense, and otherwise properly constituted, subject to have its orthography changed by a subsequent author, on the ground that a proper construction from its classical roots would result in a different spelling? No, 21. Doubtful, 3. Yes, 19. No answer, 2.

X. If the previous question be answered in the affirmative, it may be further enquired whether an author has a right to assume that a given name is derived from classical roots, when the author of the name did not so state, and on this assumption to proceed to change the said name to make it agree with the assumed proper construction in any case? and especially when by the asserted reformation the generic name becomes identical with one previously proposed for some other animal or plant, and hence will fall into synonymy? No, 25. Doubtful, 2. Yes, 6. No answer, 12.

Example. Schumacher described a genus which he called *Paxydon*, giving no derivation. A subsequent author described a genus *Pachydon*, giving the derivation. A third writer assumed that Schumacher's name had the same derivation as *Pachydon*, and that both, if correctly written, would be *Pachydon*. The last mentioned then proposed a new name for *Pachydon*, which he had thus made to appear preoccupied. Was this allowable? No, 26. Doubtful, 3. Yes, 8. No answer, 8.

XI. Should a generic name, otherwise properly constituted, but derived from the specific name of its typical species, or similar to that of one of the species included under it, be rejected on that account? No, 40. Doubtful, 4. Yes, 1.

Note. It is proper to state that this is an important question, since Linnæus himself, and others, formed many generic names in this manner, and a large number of such names are currently accepted, especially in botany and among vertebrate animals.

XII. Shall a subsequent author be permitted in revising a composite genus (of which no type was specified when it was described) to name as its type a species not included by the original author of the genus in that latter author's list of species given when the genus was originally described? No, 37. Doubtful, 2. Yes, 5. No answer, 1.

Example. Linnæus described a genus *Chiton* with a very few species. After many species had been described by others, a later author divided the genus into a number of genera, and reserved the name of Chiton (restricted) for a species described many years after the death of Linnæus and belonging to a section of the *Chitonidæ* unknown to Linnæus; while to the Linnæan Chitons he gave new appellations.

XIII. When an old genus without a specified type has been subdivided by a subsequent author, and one of the old species retained and specified to be the type of the restricted genus bearing the old name,—is it competent for a third author to discard this and select another of the original species as a type, when by so doing changes are necessitated in nomenclature? No, 39. Doubtful, 4. No answer, 2.

XIV. Shall an author be held to have any greater control over or greater privileges with relation to names of his own proposing, after the same have been duly published, than any other subsequent author? No, 40. Doubtful, 2. Yes, 2. No answer, 1.

XV. For instance, when an author describes a genus and indicates a species as its type, is it allowable for him subsequently to substitute any other species as a foundation for his genus, or to use the original type as a foundation for another new genus? No, 38. Doubtful, 1. Yes, 2. No answer, 4.

XVI. If an author describes a genus and does not refer to it any then or previously described existing species, can the genus be taken as established? No, 33. Doubtful, 7. Yes, 1. No answer, 4.

XVII. If an author applies a specific name to an object without referring it to some then or previously described genus, is the specific name entitled to recognition by subsequent authors? No, 33. Doubtful, 4. Yes, 7. No answer, 1.

XVIII. When a generic name has lapsed from sufficient cause into synonymy, should it be thenceforth entirely rejected from nomenclature? or should it still be applicable to any new and valid genus? Reject, 19. Accept, 23. Doubtful, 1. No answer, 2.

XIX. Should a name which has been once used in one subkingdom, and has lapsed into synonymy, be considered available for use in any other if not entirely rejected from nomenclature? No, 20. Doubtful, 1. Yes, 18. No answer, 6.

XX. Should a name be liable to be changed or a later one substituted for it, if the original be supposed to be inapplicable or contradictory of the characters of the species or genus to which it was applied? No, 28. Doubtful, 3. Yes, 13. No answer, 1.

Example. A fish without teeth was named *Polyodon* which name had come into use; when a later author substituted *Spatularia* on the ground that *Polyodon* was inapplicable.

XXI. Is it advisable to fix a limit of time, beyond which a name which has been received without objection during that time shall be held to have become valid, and no longer liable to change from the resuscitation of obsolete or uncurrent but actually prior names? No, 28. Doubtful, 1. Yes, 13. No answer, 3.

XXII. If so, what shall this period be? No answer, 35. The others range from 10 to 100 years.

XXIII. Should it be permitted to alter, or replace by other and different appellations, class, ordinal and family names, which owing to the advance of Science and consequent fluctuation of their supposed limits have become uncharacteristic? Yes, 30. Or should these also be rigidly subject to such rules of priority as might be determined on for generic or specific names? No answer, 4. Yes, 11.

XXIV. Should or should not absolute certainty of identification be required before it be permissible to reject a modern and generally adopted name in favor of a prior but uncurrent designation? Yes, 38. Doubtful, 2. No answer, 5.

Note. Many of the old descriptions of species, sufficient for identification when few species were known, are entirely insufficient at the present day to distinguish between allied species. Should, therefore, a modern specific name with a recognizable description be made to yield to an older name unless the identification can be made beyond any cavil?

XXV. Is it desirable to adopt any classification of periodical literature by which certain exclusive channels for publication of descriptive papers in Natural History shall be designated for use by authors who desire to secure the rights of priority for new names proposed by them? No, 26. Desirable but impracticable, 9. Yes, 8. No answer, 2.

Note. An affirmative answer will imply that names which may be proposed through other than the designated channels, after the latter shall have been decided upon, shall not be entitled to recognition in questions of priority.

XXVI. Is it desirable to adopt any analogous rule in relation to the character or extent of distribution of any independent publication or pamphlet to which it must conform, on pain of losing its right to recognition? No, 21. Desirable but impracticable, 10. Yes, 14.

Note. If the answer to either or both of the two preceding questions be affirmative, a note specifying the nature of the proposed classification or restrictions may be appended to this list.

XXVII. Should a series of rules be recommended for adoption by the Association, would you be guided by these recommendations in cases where they might not agree with your own preferences? Yes, 29. Yes, with reservations, 15. No, 1.

LIST OF NATURALISTS FROM WHOM REPLIES TO THE CIRCULARS HAVE BEEN RECEIVED.

J. A. Allen, Museum of Comparative Zoology.
W. G. Binney, Burlington, N. J.
Richard Bliss, Jr., Cambridge, Mass.
Dr. Thomas M. Brewer, Boston Society of Natural History.
Dr. P. P. Carpenter, McGill University.
S. F. Clark, Johns Hopkins University.
T. A. Conrad, Philadelphia Academy of Natural Sciences.
Dr. J. G. Cooper, California.
Prof. E. D. Cope, Philadelphia.
W. H. Dall, Smithsonian Institution.
Prof. J D. Dana, Yale College.
Dr. J. W. Dawson, McGill University.
W. H. Edwards, West Virginia.
S. W. Garman, Museum of Comparative Zoology.
Dr. T. N. Gill, Smithsonian Institution.
Dr. Asa Gray, Harvard University.
A. R. Grote, Buffalo Academy of Sciences.
Dr. Herman Hagen, Museum Comparative Zoology.
Dr. Geo. H. Horn, Philadelphia.
Prof. Alpheus Hyatt, Boston Society of Natural History.
Ernest Ingersoll, New York.
W. P. James, Cincinnati, Ohio.
Prof. D. S. Jordan, Indiana.
Dr. J. L. Leconte, Philadelphia Academy of Natural Sciences.
Dr. Joseph Leidy, Philadelphia Academy of Natural Sciences.
Dr. James Lewis, Mohawk, N. Y.
Theodore Lyman, Museum of Comparative Zoology.
T. L. Mead, New York.
S. A. Miller, Cincinnati, Ohio.
Dr. A. S. Packard, Peabody Academy of Sciences.
F. W. Putnam, Museum of Comparative Zoology.
Prof. C. V. Riley, United States Entomological Commission.
Prof. C. Rominger, State Geologist, Michigan.
Dr J. T. Rothrock, University of Pennsylvania.
S. H. Scudder, Cambridge, Mass.

Prof. N. S. Shaler, State Geologist of Kentucky.

Herman Strecker, Reading, Pa.

Prof. Cyrus Thomas, United States Entomological Commission.

Geo. W. Tryon, Jr., Philadelphia Academy of Natural Sciences.

P. R. Uhler, Peabody Institute, Baltimore.

Sereno Watson, Harvard University.

Dr. C. A. White, United States Survey of the Rocky Mountain Region.

J. F. Whiteaves, Paleontologist to the Canadian Geological Survey.

Prof. R. P. Whitfield, American Museum of Natural History, N. Y.

Dr. H. C. Yarrow, United States Army.

Two accidentally unsigned.

WORKS REFERRED TO.

Beside the Linnæan canons the following works, beside some not quoted in the body of this report, have been consulted and are referred to by the abbreviations which here precede their titles.

A. Nomenclator Zoologicus, auctore L. Agassiz. Soloduri, 1842–46. 4to. (Præfatio.)

A. Ag. Revision of the Echini; Alexander Agassiz. Cambridge, 1872. 4to. (Preliminary Remarks on Nomenclature.)

B. A. Rules for Zoological Nomenclature, authorized by Section D of British Association at Manchester, 1842. 8vo, pp. 26.

B. A. (Modified do.) Report British Assoc., Birmingham, 1865. 8vo, pp. 28. (See Verrill.)

Bourg. Methodus conchyliologicus denominationis, par M. J. R. Bourguignat. Paris, 1860. 8vo, pp. 88.

Br. Index palæontologicus, von Heinrich G. Bronn, vol. III. Stuttgart, 1848. (Ueber Nomenclatur, pp. lviii–lxviii.)

DC. Lois de la Nomenclature botanique, rédigées et commentées par M. Alphonse de Candolle. Paris, 1867. 8vo, pp. 60.

Gray. Review of Bentham and Hooker, Genera plantarum, by Asa Gray, LL. D. (in) Am. Jour. Sci. and Arts, Jan., 1863, p. 134.

G. R. G. From the prefaces to the "List of the Genera of Birds," and to the "Genera of Birds," with some additional remarks. London, n. d. 8vo, pp. 10. (Privately printed by Geo. R. Gray, about 1870.)

Herrm. Indicis generum malacozoorum primordia, conscripsit A. N. Herrmannsen. Vol. I. Cassel, 1846. 8vo. (Leges nomenclationis, pp. vii–xiv.)

LeC. On some changes in the nomenclature of North American Coleoptera, which have recently been proposed. By John L. LeConte, M. D., (in) Canadian Entomologist, Oct., 1874. 8vo, pp. 185–197.

LeC. On Entomological Nomenclature, by the same in the same; Nov., 1874. Part I, pp. 201–206. Dec., 1874. Part II, pp. 207–210.

Lew. A discussion of the law of priority in entomological nomenclature, etc., by W. Arnold Lewis. London, 1872. 8vo, pp. 86.

R. Rules to be submitted to the Entomological Club of the A. A. A. S. (J. L. LeConte, W. Saunders, C. V. Riley), 1876. 8vo, pp. 6.

Scud. Canons of systematic nomenclature applied to the higher groups. S. H. Scudder (in) Am. Journ. Sci. and Arts (3). III, pp. 348. 1872. 8vo.

Scud. Historical sketch of the generic names proposed for butterflies, a contribution to systematic nomenclature, by Samuel H. Scudder. Salem, 1875. 8vo, pp. 293.

Th. On European Spiders, by T. Thorell; Part I, Observations on Nomenclature. Upsala, 1869. 4to, pp. 88.

V. Notes on the modified Rules for Zoological Nomenclature, B. A., 1865. By A. E. Verrill, in the Am. Journ. Sci. and Arts, xlviii. July, 1869.

DISCUSSION OF THE SUBJECT OF NOMENCLATURE.

GENERAL PRINCIPLES.

§ I. Natural History cannot progress, nor can the study of its various branches be carried on and properly correlated, without a regular system in nomenclature which shall be recognized and employed by the majority of naturalists of all countries. (DC.)

§ II. The rules for nomenclature must be impartial and founded on motives sufficiently clear and weighty to promote their general comprehension and acceptance. (DC., B. A.)

§ III. The essential principles in everything which relates to nomenclature are (1) the attainment of *fixity* in the designations for organized beings, (2) the avoidance of names or methods of applying names calculated to result in errors or to throw science into confusion, and lastly (3) to avoid the unnecessary creation of names. (DC.)

Other considerations, such as grammatical accuracy in the formation of names, their regularity or euphony, etc., are relatively less important. (DC.)

§ IV. No usage conflicting with the rules and liable to introduce error or confusion can be maintained. When no grave objections of this nature are liable to be raised, it may happen that an ancient usage may be conserved without opposition, but all should carefully guard against the imitation or extension of such practices. In the absence of a rule, or if the application of the rules be doubtful, an established usage may be taken as a proper guide. (DC.)

It is impracticable not to recognize a certain right in *usage*, for, by the maintenance of familiar names and useful forms, clearness and precision are often gained. But it is never desirable to perpetuate a serious error for the small advantage of following a habit. (DC.)

§ V. The principles and forms of nomenclature should be as similar as possible in Botany and Zoology. (DC.)

The manner in which Botany and the different branches of Zoology have reached their present state, being far from uniform, and the nature of the organisms treated of being dissimilar, an absolute identity in the application of nomenclature is impracticable even if it were wholly desirable. The fundamental principles, however, and the end to be attained, are the same in both branches of study.

§ VI. Scientific names are of the Latin form or language. When taken from another language they are to be rendered in the manner of Latin words and take a similar termination. If translated into the vernacular for use in a popular or familiar manner the resemblance to the Latin original should be preserved as nearly as possible. (DC., B. A., Th., etc.)

§ VII. Nomenclature comprehends two kinds of names: (1) terms which express the relative value of groups which are comprised each in another. (2) Particular names for each group of organisms known to exist, appellative words which are names and not definitions.

On the Subordination and Designation of Groups belonging to the First Category of § VII.

§ VIII. The following table indicates the two series.

REGNUM VEGETABILE.		REGNUM ANIMALE.	
.....	.....	Subregnum.	Subkingdom.
Classis.	Class.	Classis.	Class.
Subclassis.	Subclass.	Subclassis.	Subclass.
.....	.....	Superordo.	Superorder.
Cohors.	Cohort.	Ordo.	Order.
Subcohors.	Subcohort.	Subordo.	Suborder.
.....	.....	Superfamilia.	Superfamily.
Ordo, familia.	Order or Family.	Familia.	Family.
Subordo, subfamilia.	Suborder.	Subfamilia.	Subfamily.
Tribus.	Tribe.	Tribus.	Tribe.
Subtribus.	Subtribe.	.....	.....
Genus.	Genus.	Genus.	Genus.
Subgenus.	Subgenus.	Subgenus.	Subgenus.
Sectio.	Section.	Sectio.	Section.
Subsectio.	Subsection.	Subsectio.	Subsection.
Species.	Species.	Species.	Species.
Subspecies, Proles.	Subspecies, Race.	Subspecies.	Subspecies.
Varietas.	Variety.	Varietas.	Variety.
Subvarietas.	Subvariety.	.....	.....
Variato.	Variation.	Variatio.	Variation.
Subvariatio.	Subvariation.	.....	.....
Planta.	Plant.	Animal.	Individual.

The above terms are more or less generally accepted; the relative values being more fully and generally recognized in botany than in zoology. In the literature of the latter branch some of the terms above mentioned are rarely found, though by no means unnecessary for careful discrimination. The term *tribe* in zoology has been used with several different values. In this, as in other respects, the inchoate condition of zoological nomenclature as compared with that of botany is clearly apparent.

§ IX. All individuals belong to a species, all species to a genus, all genera to a family, all families to an order or to a cohort, all orders or cohorts to a class. (DC.. B. A.) In some species varieties or variations are recognized, and even more numerous modifications in some cultivated plants; botanical orders are often divided into tribes, and genera into sections. Intermediate groups are distinguished by the prefixes *sub* and

super, the former being intermediate between the rank of the term to which it is prefixed, and the next lower, the latter between the same term and the next higher.

The botanical terms are not precisely interchangeable with those used in zoology, owing to the difference in the subjects classified and for other reasons; this is especially the case with the terms order and family, in the two series. A special series of terms to indicate *sports*, *hybrids*, etc., is in use in botany which is exhaustively treated of by DeCandolle.

§ X. The definition of each of these terms or names of groups varies, up to a certain point according to the state of science or the views of the individual writer using them, but their relative rank, sanctioned by usage, cannot be inverted. No classification containing inversions, such as a division of a genus into families or of a species into genera can be admitted. (DC.)

§ XI. In botany subdivisions of a species are usually indicated by figures (1, 2, 3, etc.) and subdivisions of varieties by Greek letters (α, β, λ, etc.), but in zoology it is a common practice to denominate the subspecies by distinct names which are appended to the specific name, as *Ovis ammon* subsp. *crassicornus*.

On the Manner of Designating Particular Groups or those belonging to the Second Category of § VII.

§ XII. Each natural group of animals or plants can have but one valid designation. (DC., B. A., Bourg., etc.) This designation by modern usage is allowed to exist simultaneously in zoology and botany without rendering either application of it invalid, but in either department it can be applied in a valid manner but once.

§ VI should be kept in mind. "We refer solely to the Latin or systematic language of zoology (and botany). We have nothing to do with vernacular designations." (B. A., Th.)

The special application of this principle to genera and species will be treated under their specific heads.

§ XIII. This designation should only be changed for the most important reasons, founded on a thorough knowledge of the facts; or on the necessity of abandoning a denomination on account of its being in conflict with the following rules or with the essential principles of systematic nomenclature. This necessarily follows from § III.

§ XIV. The form, number and arrangement of the names are dependent on the nature of each group, according to the rules which follow.

DENOMINATION OF THE HIGHER GROUPS.

GROUPS OF HIGHER VALUE THAN FAMILIES OR BOTANICAL ORDERS.

§ XV. The names of these groups are taken from some one of the principal characters. They are expressed by single words of Greek or Latin

origin in which a certain harmony of form and termination is preserved for groups of similar nature. Ex. *Phanerogamæ, Cryptogamæ; Cephalopoda, Gasteropoda; Raptores, Scansores; etc.* (DC., etc.)

Compounds of Greek and Latin words are inadmissible (Bourg.) Nomina sesquipedalia fugienda sunt (Linn.) In cryptogamic botany ancient names of families such as *Musci, Filices*, etc., have been employed as names of classes or subclasses. Botanical cohorts or subcohorts are designated by the name of one of their principal families with the termination *ales*. (DC., etc.)

BOTANICAL FAMILIES OR ORDERS.

§ XVI. The families (*ordines*) in botany are designated by the name of one of their principal genera, with the termination *aceæ*. Ex. *Rosa, Rosaceæ; Ranunculus, Ranunculaceæ.*

Usage has justified the following exceptions.

1. When the genus from which the name of the family is taken ends in Latin with *ix* or *is* (genitive *icis, idis or iscis*) the termination *iceæ, ideæ or ineæ* is permitted; as in *Salicineæ* from *Salix; Berberideæ* from *Berberis; Tamariscineæ* from *Tamarix.*
2. When the genus from whence the name of the family is derived has a name of inconvenient length, and there is not in the family a tribal name formed from the same generic name, the termination *eæ* is admitted; as *Dipterocarpeæ* from *Dipterocarpus.*
3. For some very large families universally known under their exceptional names, the ancient designation is preserved, as *Cruciferæ, Compositæ, Gramineæ*, etc.
4. An old generic name no longer preserving that rank, but applied only to a section or even a species, may be maintained as the base of a family name, as *Hippocastaneæ* from *Æsculus hippocastanum.* (DC.)

ZOOLOGICAL FAMILIES, SUBFAMILIES AND TRIBES.

§ XVII. The names of zoological families are best formed by adding the termination *idæ* to the name of the earliest known or most characteristic genus contained in them; and of subfamilies by adding the termination *inæ:* this should be done by changing the last syllable of the genitive case into *idæ* or *inæ.* Ex. *Strix, Strigis, Strigidæ;* not *Strixidæ; Buceros, Bucerotis, Bucerotidæ;* not *Bucerosidæ*, or *Buceridæ.* (DC., B. A., R., Bourg., D'Orbigny, etc.)

This practice is strongly recommended in both editions of its rules by the British Association Committee. It has been adopted so generally by modern authors, and its simplicity and convenience are so great, that it is not necessary to enlarge on its claims for consideration. Thorell suggests *oidæ* as a termination, which is certainly less euphonious, if in some cases more classical. Scudder and a few others would attempt to retain old forms, however diverse, a course apparently both impracticable and undesirable.

There are a few generic names, which, it is claimed, will not readily receive these terminations, and some objections have been made to insisting on the universal application of this terminology.

The desirability of uniformity and the self-evident convenience of being able to recognize the value of a group at a glance are weighty reasons in favor of the practice which, it appears to the Reporter, may safely be left to the common sense and good-

taste of naturalists, which in the course of time will practically decide the question; especially since no fundamental principle is endangered by allowing some latitude in the matter.

§ XVIII. Botanical subfamilies (*subordines*) are formed from the name of one of the genera contained in them with the termination *eæ* or *inæ* and also the names of tribes and subtribes which take the termination *ee*. Ex. *Roseæ* from *Rosa*, etc.

Permanency of Names of the Higher Rank.

§ XIX. Names of higher rank than genera, with the fluctuation of their limits caused by the advance of science, are not rigidly subject to the *lex prioritatis*.

While this generalization has not been formally enunciated in the B. A. rules it has become practically the general usage of naturalists. Thorell explicitly adopts it, and indeed it is impracticable to follow any other course, especially in relation to the more ancient names. A time will doubtless arrive when mutations in the names of the higher groups, particularly families, will be as unnecessary as they are undesirable, but in zoology that period has not yet come.

It should be clearly borne in mind that such changes are only allowable when by mutation of the characters or through newly discovered facts, the name in question has become glaringly erroneous, or liable to introduce errors or confusion into science. In family names this occurs most often when a genus from whose name that of the family may have been taken is removed from association with the majority of genera which that family has included, and the said genus is inserted in another family which has already a well established name. Also, when a large number of genera are redistributed into families, widely differing in their limits from those in which they had previously been known. In either of these cases the liability to induce error may be so great as to render a new name desirable. The answers to query XXIII of the circular indicate that a majority of American naturalists concur in this conclusion.

On names of Genera and Subdivisions of Genera of Higher Rank than Species.

§ XX. Genera, subgenera, or sections, receive names, preferably substantives, which bear the same relation to each other that the proper family or surnames of individual men do to one another. (DC., Bourg.)

These names may be taken from any source whatever, or may be framed in an absolutely arbitrary manner, subject to the following conditions. (DC., G. R. G.)

De Candolle justly remarks that it is with generic names as with our patronymics. Many surnames are inconvenient or even absurd from bearing an adjective form, from having an inapplicable meaning, on account of being difficult to pronounce, or for some other reason. But, since they actually exist, why should they be changed? It is not the end of science to make names. She avails herself of them to distinguish things. If a name is properly formed and different from other names the essential points are attained.

Generic names may be taken from certain characters or appearances of the group, from the chief habitat, names of persons, common names and even from arbitrary combinations of letters. It is enough if they are properly constructed and do not lead to confusion or error.

As long as these matters are not judged by this most important principle, so long must nomenclature suffer from the proposition of rules admitted by some and rejected by others. (DC.)

Differing names are sometimes formed in honor of the same person when their names lend themselves to it. *Pittonia* and *Tournefortia* are derived from Pitton de Tournefort; *Brownia* and *Brunonia* from Brown, etc. These names should be preserved for they cannot be confounded in speech or in the tables. Certainly, if after *Brownia* had been proposed there should appear a naturalist named *Brunon*, no one would criticise a genus *Brunonia;* hence *Brunonia* is an admissible generic name. (DC.)

The B. A. committee strongly object to names arbitrarily formed and having no meaning. On the other hand, if euphonious and constructed according to the Latin form, they are not without their advantages. Yet it is certain that names having a definite meaning are much to be preferred.

§ XXI. Minor subdivisions of a genus may be indicated by a name, or, if of less value than a subgenus, may preferably bear merely a letter or a number without a name. (DC., etc.)

§ XXII. When the name of a genus or of one of its subdivisions is derived from the name of a person, it should be constructed in the following manner. (Bronn, Bourg., Th.)

A. The name disembarrassed from all titles and all preliminary particles is terminated by *a* appended to the form of the genitive case, thus taking on a feminine form.

The following examples illustrate the method both for generic and specific names.

Name.	Brun	Bruni	Bruno	Brunus.
Genitive.	Bruni	Brunii	Brunoi	Brunusi.
Generic form.	Brunia	Bruniia	Brunoia	Brunusia.
Adjective form.	Brunianus	Bruniianus	Brunoianus	Brunusianus.

Name.	Bruna	Brune	Bruny.
Genitive.	Brunæ	Bruni	Brunyi or Brunii
Generic form	Brunæa	Brunia	Brunyia or Bruniia
Adjective form.	Brunæ	Brunianus	Brunyianus or Bruniianus.

B. The syllables which are not modified by this termination preserve exactly their original orthography, even to the letters or diphthongs employed in certain languages, but which are not used in the Latin tongue. However, the *ä, ö, ü*, of Germanic languages become *æ, œ, o;* the é and è of the French language become *e; y* at the end of a word of one syllable is treated as a consonant (*Quoy. Quoyia; Gay. Gayia*), and mute *e* final becomes *i*, or is dropped entirely (*Perouse. Perousia*).

To this proposition the B. A. committee agree, and it is generally followed.

C. The genitive form is used for specific names when the proper name is that of the person who collected or originally described the species, the adjective form is proper in all other cases. Thus *Corrus corax*, Brun non Linnæus, or a new *Corrus* collected by Brun, would be *C. Bruni*. A *Corrus* named after one's friend Brun, or an ornithologist Brun, would be *C. Brunianus*. (Bourg.)

An adjective form, however, must in no case be given to a generic or subgeneric name; e. g., *Wolfartaria* Gray, named after Mr. Wolfart should be *Wolfartia*. (B. A., Bourg.)

§ XXIII. It is highly undesirable that genera should be dedicated to persons not in some way connected with the study of the natural sciences, or with the collection of materials upon which that study is based. (B. A., Bourg.)

The recommendations of the B. A. committee contain an objection to personal names in zoological genera, but the practice has been carried to such an extent that even if it were less desirable, any prohibitory rule or recommendation would be unavailing. However, names having a modern political or religious significance should be particularly avoided.

§ XXIV. Naturalists who may propose generic names will conform to good taste and benefit nomenclature by regarding the subjoined recommendations.

A. Avoid very long names and such as are difficult to pronounce. As a general rule it may be recommended to avoid introducing words of more than five syllables. Ex. *Craxirex: Eschscholtzia; Thecodontosaurus; Strongylocentrotus*, etc. (DC., B. A., etc.)

B. Indicate the etymology of each name.

Great confusion has resulted from endeavors on the part of authors to correct names of which the etymology was uncertain, but which seemed to them to be erroneously constructed. When the etymology is given this question can be accurately and promptly decided and no confusion result. (B. A., DC., etc.)

C. If an author has proposed a genus which has not been admitted, he should most carefully avoid creating another under the same name.

Nothing is more inconvenient in synonymy than to have to explain that a certain genus of any author is not the genus bearing the same name and of the same author, but of a different epoch. In general, a generic name which is known to have once been used in botany or zoology, should be studiously avoided forever afterward in any other connection in the department in which it was once introduced. (DC., B. A., etc.) See under head of names to be rejected.

D. Avoid forming names from barbarous or savage tongues unless they may be found more or less frequently cited in books of travel, and present a euphonic combination easily adapted to the Latin forms. (DC.)

E. Recall, if possible, in the composition or termination of the name the affinities or analogies of the genus. Ex. Many genera of fossils appropriately end in *ites*, many of ferns in *pteris*, etc.

F. Avoid all adjective names.

The names of genera are in all cases essentially substantive, and hence adjective terms cannot be employed without violence to grammatical construction, and their use is *prima facie* evidence of a want of good taste. The same may be said of names in the genitive case which are wholly inadmissible without reformation. (B. A., DC., Ver.)

G. Avoid giving names which in sound or spelling closely resemble other names already proposed, even when the etymology of the two words is diverse. Ex. *Leucodore, Leucodora; Otostomia, Odostomia, etc., etc.*

The danger of confusion in such cases is self-evident, and the naturalist mindful of the objects of nomenclature will endeavor to avoid them.

H. In compounding a name from two other names, the essential or radical parts of both should be retained and the changes confined to their variable terminations. (B. A., DC., Th.)

A name compounded of the first half of one word, and the latter half of another, is an ungrammatical monstrosity; e. g., *Loxigilla*, from *Loxia* and *Fringilla*.

In other cases when the commencement of both words is retained, the excision may still be too great; e. g., *Bucorrus* from *Buceros* and *Corvus*.

In general, compound words are open to objection from their too great length, or the liability of introducing a barbarism in endeavoring to render them shorter; but, when compounded with care and not too long, they may occasionally be used with advantage in designating intermediate genera. (B. A.)

I. Avoid compounding names from two different languages. (B. A., Th.)

Such names are great deformities in nomenclature, and are, when one of the parts is of an adjective character, reasonably considered by most authors as subject to reformation or rejection.

J. Geographical names, being for the most part adjectives, should be avoided in naming genera. (B. A.) The termination *ensis* is only applicable to names of species derived from the name of their habitat.

K. Technical names expressing trades or professions should only be used when they have a special relation to the habits or characters of the organism designated. (B. A.) Ex. *Arricola; Pastor; Regulus*, etc. If this caution were disregarded, such names would be highly objectionable.

L. Mythological names are best applied in cases where a direct allusion can be traced between the narrated actions of a personage and the observed habits or structure of an animal. Thus when the name *Progne* is given to a swallow, *Clotho* to a spider, *Nestor* to a gray-headed parrot, etc., a pleasing and beneficial connection is established between classical literature and natural science. (B. A.)

M. Names expressing positive characters are to be preferred to comparative names in most cases, though occasionally a diminutive may be employed without disadvantage.

§ XXV. In naming subgenera or sections of a genus beside the recommendations under the last head, the following additional precautions may advantageously be attended to. (DC.)

A. For the principal divisions of a genus, if it be decided to apply names to them at all, it is well to adopt such as recall the genus itself by some modification or addition.

B. The chief modifications in use in nomenclature are as follows:—before a Greek derivative *Eu* and *pseudo;* after it *astrum, oides*, or *opsis;* before a Latin derivative *sub;* after it *ella, una, ina, ites*, etc. Usage has justified to some extent the application of these modifications to words of uncertain etymology or arbitrary formation, in connection with which the Greek syllables are best entirely avoided.

C. The application of these modifications should be governed by the subjoined restrictions.

(1) The prefixes *pseudo* and *sub* should, especially the latter, be reserved for use with specific names, though the former may rarely be applicable to the name of a generic group which has been confounded with another whose name is not of Latin extraction. *Eu* may be used before generic names when they are derived from the Greek language.

So far as specific appellations are concerned, *pseudo* may be employed when it is desired to connect the name of a species with that of another with which the former has been confounded. (Bourg.)

Sub may be used in designating a new species before the name of another with which the first has intimate relations. It has also a few legitimate Latin compounds which may be used for specific names, such as *subterranea*, etc.

(2) The suffixes *ella, una, ina, ites* (Latin), and *astrum, oides, opsis* (Greek), etc., may be applied to generic or specific names.

The termination, *ella, una, ina*, are used at the end of generic names derived from the Latin, to indicate that the genus indicated by the radical to which the termination is appended, resembles, in some way, the new genus.

They are also used in reforming a name which is inadmissible for any reason, in order to preserve a convenient similarity. For instance, *Cæcilia*, if employed for a shell (but already in use in vertebrates or insects), might be modified to *Cæcilianella*, in order that convenience in the consultation of tables or indices might be conserved for the new name in connection with the old one.

In the first sense these suffixes are also used in forming specific names.

The termination *ites* is found convenient for designating fossil organisms analogous to the living form, whose generic name is the radical to which *ites* is appended. It is rarely used with specific names. The terminations *astrum, opsis, iscus*, etc., may be used in connection with generic or specific names.

Bourguignat suggests that *astrum* be appended to the name of a genus to indicate its typical subdivision, and be reserved for this purpose, but this has not been adopted.

A subdivision of a genus should not be formed by adding to the name of the genus as a radical, the termination of *opis* or *oides*, but on the contrary these terminations should be reserved for subdivisions, which resemble another genus by adding them to the name of that other genus, when it is of Greek origin. (DC.) Since a subgenus necessarily recalls or resembles its genus the announcement of the fact in its name is a work of supererogation. To annul such names which have been already imposed, however, would be still more inconvenient in spite of their objectionable character.

The termination *oides* is inelegant when applied to generic names or those of higher rank, and is better reserved for specific names of Greek or barbarous (never Latin) origin, and used in the following cases, only, if at all.

a. When the radical of the specific name is the name of a genus which it resembles: e. g., *Helix naticoides* for a species resembling a *Natica*.

b. When the radical is the root of the name of another species which the new one resembles; e. g., *Helix carascaloides*, a species like *H. carascalensis*, or *Unio Moquinoides* for a species like *Unio Moquini*.

One single apparent exception to the compounding of Greek and Latin has been consecrated by usage; namely, *oroides* from *orum and* εἶδος; this has arisen from the absence of euphony in the correct form, *ooides* (ᾠόν and εἶδος). (Bourg.)

D. For subsections or groups of species, the name of the species, around which the others may naturally be clustered, may be used with the termination *iana*, as a group of species of *Helix* related to *H. pomatia* may be indicated by the term *Pomatiana*. (Bourg.)

E. Avoid, in designating sections, names which have previously been employed for genera or sections of other genera.

Sections are chiefly used in botany, being seldom named in zoological literature. Even in botany they are not usually cited in synonymy, and hence it has happened that the name of a section has been permitted to exist simultaneously with an identical word applied to a genus, or the section of another genus.

This, however, should be avoided, especially as, at some later day, the Sections may be advanced to subgeneric or generic rank.

F. When the name of a section is cited it is always announced in conjunction with the generic and specific names, and is placed between them in parentheses. (DC.)

G. In defining new genera or subgenera, a typical species should always be mentioned to serve as a standard of reference. (B. A.)

Of Specific Names and Names of Subdivisions of Species.

OF THEIR FORMATION.

§ XXVI. Each species, even when it is the only one of its genus, is designated by the name of the genus to which it belongs followed by a name called specific, which consists of a single simple or compound word, and has usually the character of an adjective. (DC., Bourg.)

See also § XXII. A. In certain exceptional cases, such as gall insects, the connection by a hyphen of a third word, with the specific name proper, when justified by usage, is not considered as an infraction of this rule. (Riley.)

§ XXVII. The specific name should, in general, indicate some feature of the appearance, characters, origin, history or properties of the species.

If it is taken from the name of a person, it is usually for the purpose of recalling the individual who described, discovered, or was in some way connected with it, or with the study of the group of which it forms a part. (DC., Bourg.)

If a mythological personage has furnished a name which has been applied to the genus, it is permissible for the species to receive the names of his family or tribe. A

series of names having a mental association with one another may be used for the species of a genus, as for instance, when a group of wood-butterflies receive the names of Indian chiefs, native to the region inhabited by those insects; or the name of various mythological heroes or warriors are associated with the respective species of a group characterized by martial colors, habits or bearing. These names, unless already euphonious, should receive a modified Latin termination as already indicated.

§ XXVIII. A specific name may be a prŏper noun or substantive, in which case it does not necessarily accord in gender with the generic name; but when the specific name has the character of an adjective, its termination should be constructed to agree in gender with the generic name.

In the first case it is frequently written beginning with a capital letter; in the second case, it should commence with a small letter. It is probable that in all cases it would be better to commence the generic name with a capital, and the specific name with a small letter, except possibly when it is derived from the name of a person.

On this point, however, naturalists are divided in opinion, usually following the rules of their respective vernaculars.

§ XXIX. The same specific name must not be used for two species of the same genus; but, to species of different genera, the same specific name may be simultaneously applied.

§ XXX. In constructing specific names naturalists will do well to regard the following recommendations. (DC., Bourg., B. A., etc.)

A. Avoid names of too great length or difficult to pronounce.

B. Avoid names which express characters common to all or nearly all the species of the genus.

Such names were formerly rejected, but the confusion thus caused in nomenclature was far worse than the want of definitiveness in the names changed.

C. Avoid geographical names taken from little known localities or of narrowly restricted application, unless the habitat of the species is known to be equally restricted.

D. When a geographical name is applied to a species, if there be a classical form of it, it is to be used in preference to the modern name (e. g., Anglia not England), unless the Latin name be extremely obscure, inharmonious, or almost unknown.

Names not represented in classical literature preserve the radical intact, latinizing only the termination.

The name of a locality is always terminated by the suffix *ensis* (e. g., a species from Caracal would be *caracalensis*).

The name of a river or other body of water, a province, a country, or a kingdom, on the contrary, is terminated by *ius*, *icus*, *inus*, *itus*, etc., if the gender be masculine; or by *ia*, *ica*, *ina*, *ita*, etc., if it be feminine; as *arabicus*, *euphraticus*, *algirus* (if the province of Algiers), *appennina*, *anglica*, *cypria*, *texasiana*, *algiriensis* (if the town of Algiers), etc., etc.

Since geographical names are often liable to change from the variation of political boundaries, they are in many cases particularly objectionable. Formerly some authors rejected them entirely, or tolerated them only when exclusively applicable. Such mutations are no longer approved by the majority of naturalists, since fixity is the fundamental principle to be regarded in nomenclature, yet as these names are liable to objection on serious grounds it is desirable to make as little use of them as possible. (See names to be rejected.)

E. Avoid using in the same genus names too closely similar in form or sense, above all those which only differ in their last letters.

A judicious naturalist, for example, will not call a species *virens* or *virescens* in a genus already containing a species named *viridis*. (B. A.)

E. Manuscript names found in the notes of a collector or on his herbarium tickets, when they are well selected, may be adopted, but not without supplying a description and stating that the name has not elsewhere been formally introduced into nomenclature.

Without these restrictions or precautions the use of MSS. names is highly objectionable, and has already been the cause of great confusion and annoyance to naturalists. The MSS. names of Beck, Solander, Leach and others, have long been stumbling blocks in the path of science from having been quoted by naturalists with no reference to the fact that they are to this day undescribed, and therefore wholly valueless.

G. Avoid names which have already been employed in the genus or a related genus, and which have fallen into synonymy. (DC.)

H. Do not dedicate a species to a person who has not discovered, described, figured nor studied in any manner, it or the group to which it belongs.

I. Avoid names similar to names employed to designate the genus to which names belong or related genera.

§ XXXI. Names of subspecies or varieties are formed like specific names, and when cited, follow the name of the species to which they are related, preceded by the abbreviation *subsp.* or *var.* They should never have a substantive character.

The practice which has lately arisen of writing these names without the abbreviation is objectionable, as incompatible with binomial nomenclature.

Of Names of Hybrids, Sports and Cultivated Varieties used in Botany.

§ XXXII. Hybrids whose origin is certain are designated by the name of the genus followed by a combination of the specific names from which the hybrid has proceeded. The name of the mother species is placed first, terminated by an *i* or an *o* and connected by a hyphen with the name of the species which has furnished the pollen; e. g., *Amaryllis vittato-reginæ.*

Hybrids of doubtful origin are named like species, and are preceded by the sign × placed before the generic name; as × *Salix capreola*, Kern.

§ XXXIII. Subvarieties, variations, and subvariations of wild plants may receive names analogous to those of varieties, or simply numbers, or letters which may facilitate their classification.

§ XXXIV. Seedlings, or sports, from cultivated plants, receive fancy names in the vernacular which should differ as much as possible from the Latin designations of species or varieties. When it is desired to cite them with botanical species, subspecies or varieties, they are indicated by the succession of the names: as "*Pelargonium zonale* Mistress Pollock." (DC.)

The above limitations, as explained by De Candolle, are necessary to prevent confusion between the principal natural modifications of a species and the illimitable number of seedlings, sports, and inferior modifications of cultivated plants, the product of gardens; whose transitory appellations, if proposed in the Latin form, would (as some have already) creep into the literature of the subject, be confounded daily with species or varieties, and produce unending complications.

Of the publication of Names and the date to be assigned to each Name or Combination of Names.

§ XXXV. The date of a name or combination of names is that of their actual publication, that is to say from the time of occurrence of such circumstances as give to the name an irrevocable publicity.

§ XXXVI. Publication consists in the public sale or distribution of printed books, pamphlets or plates. To this category botanists add the distribution or sale of specimens of the plants described, to which written or printed tickets containing the proposed new names are attached. (DC.)

To constitute publication nothing less than the insertion of a distinct exposition of essential characters in a printed book can be deemed sufficient. (B. A.)

Satisfactory plates or figures which express the essential characters of the organism concerned, and on which the proposed name is engraved or printed, are generally held to be equivalent to a definition.

The exception in favor of published herbaria by botanists appears injudicious, and is the result of an ancient usage which fortunately has never attained in zoology, and as a method of publication in modern days can be seldom necessary and never advisable.

§ XXXVII. A communication in a public assembly, of names applied to specimens in collections, the ticketing of plants in public gardens, or the reading of a paper containing new names before a scientific society, does not constitute publication. (DC., Th., Benth., V., B. A.)

Communications to a public assembly, unless published in an immediate literal report of the meeting, rest only on the uncertain recollections of the audience. Labels in public museums and gardens may be transposed or replaced from hour to hour. Communications to a society may be subject to amplification, correction or revision, up to the time of printing. In all the above cases the *fact* of publication cannot be placed above question.

The inadmissibility of adopting the date of reading of a paper is shown by supposing a case in which it failed altogether to be printed. No one would then assert that it had actually been published. Yet that such honor or credit as may be due to the original discoverer of a fact, can be, and is, secured to him by such an announcement of it, whether he be the first to print it or not, no one will deny. This seems to be the principle contended for by the few who demand priority from the date of reading. It is possible that some believe that credit or honor is secured by the application of new names, but scientific nomenclature, owing its right to exist to the fundamental principle of fixity, should not be allowed to suffer from considerations of this nature.

That the majority of American naturalists concur in the above is manifest from the replies to query V of the circular before alluded to.

§ XXXVIII. The date borne by a publication is presumed to be accurate until the contrary is proved. (DC.)

It is, nevertheless, well known that in some cases this date is not correct, or represents the presentation instead of the publication of the matter bearing it. This is, for instance, the case with several of D'Orbigny's works and with the transactions of some learned societies.

Such absence of frankness and plain dealing, in matters where the utmost precision is desirable, is highly reprehensible. It would hardly be unfair in instances where a doubt arises as to priority between an honestly dated work and one issued as above, to throw the *onus probandi* on the publishers of the latter.

§ XXXIX. A species is not to be considered as named unless both generic and specific names are simultaneously applied to it. (DC.)

This follows from § XXVI, and the majority of the replies to query XVII of the circular concur in it.

§ XL. A species announced in a publication with both generic and specific names, but without any description, cannot be considered as published. It is the same with a genus simply announced by name. If, subsequently, the author or some one else, makes public what this name signifies, the date of the second publication is the only one to be taken account of. (DC.)

A specific name without a generic name, or a combination of generic and specific names without a description of any kind, is nothing. They are empty words without sense. They only acquire a value from the time when some one gives them sense by completing them.

It may be said that there are specific descriptions so short or badly made as to signify almost nothing, and hence these should be disregarded as incompletely published, or names pure and simple should be admitted. There is, however, a difference between the two cases. The absence of all characterization of a name is a definite, positive fact. The insufficiency of a description is something vague, which may be contested. Besides, an apparently insignificant word may sometimes lead to the identification of a species. (DC.)

In revising a group in which such names occur, the naturalist who desires to avoid multiplication of synonyms may choose to adopt the unpublished name; a course which is to be commended only when by some particular circumstances the absolute identity of the group about to be named, with that intended by the author of the unpublished name, can be established. (G. R. G., etc.)

§ XLI. A generic name, accompanied by a description, but without a reference to it of any definite species, may be considered as published when the organisms to which it is intended to refer, are unmistakable.

Compare circular, XVI.

§ XLII. A generic name unaccompanied by a description, but under which, as type, a single new species is fully described or satisfactorily figured, and concerning which there can be no uncertainty, may be admitted as published. Conversely, when a generic name is fully characterized, and a new specific name without a description is appended to it as the type of the new genus, and about which no doubt can be entertained, the species may be regarded as published. (Th.)

The practices mentioned are doubtless highly objectionable. But in the first case the generic characters may be regarded as included in the specific diagnosis, and in the second the specific characters may be considered as expressed in the generic description; in either instance a doubt might reasonably exist as to which of all the characters of a new organism were to be regarded as generic, and which as appertaining to the species.

This differs from the cases in which a generic name without a diagnosis is placed before the names of a number of species then or previously described. In these instances, if there are characters warranting the allocation of species, and separating them from other genera, it is the duty of the propounder of the genus to indicate them to the best of his ability. If too ignorant or too indolent to attempt the task of differentiation in words, his work may safely be regarded as unworthy of recognition. (B. A., II.)

§ XLIII. Naturalists will do well to bear in mind the following suggestions:

A. Indicate exactly the date of publication of each work or portion of a work, or of the distribution of named specimens of plants under § XXXVI. (DC.)

It would be very useful if scientific journals or works on bibliography would denote the exact date of reception or actual publication of volumes or plates appearing successively, or in which one is liable to be deceived by the title pages, or where doubt arises from the absence of dated title pages. This is especially the case with works appearing in parts. In regard to plants in well conducted herbaria, the date of reception (which is almost always that of distribution) is usually noted on the labels. (DC.)

B. Do not publish a name without clearly indicating the nature of the group (tribe, genus, section, species or variety) to which it is supposed to belong. (DC.)

C. Avoid mentioning or including in any publication unaccepted manuscript names, above all when the persons who gave these names have not formally authorized their publication. (DC.)

To publish a name which cannot be adopted, or which is undefined by the person citing it, or some previous author, is wantonly to throw a synonym into circulation, at least in tables and bibliographies.

Our nomenclators would be of double size if they contained all the names which exist in travellers' note books, museum and herbaria, and which have not the slightest value. Names of this kind when printed are still-born. Why then augment their number unless at least the author asks that they be made public.

Of the Precision to be given to Names by the Citation of the Author who First Published them.

XLIV. To be exact and complete in the indication of the name or names of any group, whatever, it is necessary to cite the author who has first published the name or combination of names in question.

A. When it is desired to indicate that the author proposed the whole name in the form in which it is cited, his name or an abbreviation of it simply follows the specific name; as *Anomia craniolaris*, Linnæus, or Lin. or L.

B. When it is desired to indicate that the application to the species of the specific name is all that is due to the author cited, the abbreviation of his name may be either (1) enclosed in parenthesis [e. g., *Crania craniolaris* (L.)]; or (2) followed by the abbreviation *sp.*, as *Crania craniolaris* L. sp.

C. When it is desired to indicate the author of the combination cited, together with that of the person who first proposed the specific name, the name of the latter or its abbreviation is usually written in parenthesis followed by the name of the author of the combination cited (e. g., *Crania craniolaris* (L.) Nilss.); or the name of the author of the combination follows the specific name separated from that of the author of the specific name by the word *ex* (example, *Crania craniolaris* Nilsson ex L.). The latter mode does away with parentheses and seems preferable.

D. When it is desired to indicate still more fully the relation of the author of the specific name to a former generic combination, the name of the author of the cited combination is followed by a parenthetical clause consisting of the name of the author of the specific appellation separated

from the designation of the genus to which he referred it by the word *sub*; as *Crania craniolaris* Nilsson (L. sub *Inomiæ*). This form is chiefly employed in Botany, and is liable to objection from its length. (cf. Lec. p. 204, et seq.)

For many years, Linnæus, Lamarck, Cuvier, Blainville, D'Orbigny and the majority of zoologists, as well as the universality of botanists, in citing a combination of words forming a specific name, appended to it as *authority*, the name of the author of the combination, whether he were the author of the specific name or not.

More lately some zoologists have followed a different method, recommended by Strickland in the B. A. rules of 1842, but which was from the first strongly combated by Agassiz, and other influential naturalists.

This method consists in appending the name of the author of the specific name in all cases without reference to the generic combination.

In deference to the said rules it has been somewhat extensively practised, though open to several objections which have been exhaustively set forth by Agassiz, D'Orbigny, Bourguignat, and De Candolle; the latter remarking that, if followed, it would cause zoological lists to resemble a city directory in which the names of individuals were classed according to the alphabetical order of their Christian names.

Numerous battles of words have taken place over the question which is, at most, not one of fundamental importance, and it appears to your Reporter that it may safely be left to the common sense of naturalists to decide.

There can be no question that the advantage of precision is with the older method, which accords with the practice of Linnæus and the spirit of the Linnæan canons, while, by the mode suggested in ¶ C, no uncertainty is permitted, and the most tender sentiment of justice, toward both the describer and the referrer of the species, is satisfied.

§ XLV. In writing the name of a species with the authority, it is unnecessary to separate the latter from the specific name by a comma. (V.)

There has been little uniformity in regard to this matter, and Prof. Verrill has judiciously suggested that "the best usage appears to be without any punctuation, the authority in this case being understood to be a noun in the genitive case, though written in the nominative form or more frequently abbreviated."

§ XLVI. A change of the diagnostic characters or the circumscription of a group does not authorize the citation of another author than the one who first published the name or combination of names.

When the changes have been considerable, to the citation of the primitive author may be added *mutatis char.*, *pro parte*, *excl. gen.*, *excl. sp.*, *excl. var.*, or such other abridged indication as may indicate the nature of the changes in the revised group, or of the group treated of. (DC.)

Whatever the changes brought about by the advance of science, in any group the fact that a certain author proposed a certain name is the one positive incident which can be recognized. (DC.)

Some authors (Riley) object to this generalization, but it appears to be generally accepted.

§ XLVII. Names published from manuscripts, unpublished catalogues, museum labels and herbaria, etc., are given precision by citing as authority the author who first published them in spite of any indication to the contrary which he may have given. Similarly, names used in botanical gardens are cited as of the author who first published them. In the full

text or synonymy, the manuscript, herbarium, museum, collection or garden, should be cited. (*Lam. ex Commers. in herb. Paris; Lindley ex horto Lobb; Martyn ex coll. Soland.; Gray ex Leach* MSS., etc.) DC.

The publication of the name is the essential fact, for it is that which preserves the name from change except for grave reasons. The publisher has taken the principal step. The traveller who has obtained a specimen, and has perhaps given it a provisional name in his collection, merits our gratitude, and may have more claims to it than the editor of the name; whence it becomes extremely proper to cite him, in the mention of the habitat or the collection accompanying the description. But it is not he who has made it public at a certain date, and if he had been consulted perhaps he would have applied another name to it. It is in the interest of precision therefore to cite, in botany, for example, the name of Spruce for a plant named and distributed by him, though described later by Bentham; and to cite Bentham for a plant of Hartweg, distributed by the latter under a number without a name, but afterward named by Bentham. It would be inexact to act otherwise, and unjust to the old naturalists. Commerson, for example, left plants in herbaria without publishing them. If they were published now, so great have been the changes in the science of Botany, they would indicate a condition of things of which that zealous collector, were he living, would be probably among the first to recognize the falsity. (DC.)

This, however, cannot be held to apply to cases where one working naturalist submits to another the results of his studies, to enable the former to complete a monograph or correctly interpret a fauna. In such instances the work may reasonably be considered a joint affair, and the names due to the one or the other as the case may be.

§ XLVIII. When an existing name is changed in value, from being raised to a higher rank or reduced to a lower rank than that it originally held, the change is equivalent to the creation of a new group, and the author to be cited is he who has made the change. (DC.)

It is a common but objectionable practice to cite the author of a section or family as the authority for a genus or order, or the reverse. By this negligence the opinion of the primitive author is misrepresented, and the reader is deceived in regard to the date of later name. (DC.)

§ XLIX. The authority following the name of an organism is, unless very short, usually indicated by an abbreviation. To effect this the particles or preliminary letters which do not strictly form part of the name are dispensed with, then the first letters are indicated without omitting any. If a name of one syllable is sufficiently complicated to be worth the trouble of abbreviating, the first consonants are indicated (Br. for Brown); if the name has two or more syllables, the first syllable plus the first letter of the second (or the first two if they are consonants) is made use of (Juss. for Jussieu; Rich. for Richard).

When less abbreviation is desirable to avoid confounding two names commencing with similar syllables, the same system is followed by giving the first two syllables with one or two of the consonants of the third, or adding one of the last characteristic consonants of the name (Bertol. for Bertoloni, to distinguish it from Bertero; Michx. for Michaux as opposed to Micheli; or Lamx. for Lamouroux as distinguished from Lamarck).

Christian names are abbreviated in a similar manner (Adr. Juss. for Adrien Jussieu; Gaertn. fils, or Gaertn f., for Gaertner junior, etc).

When a usage is established for an old name in some other way it is better to follow it, as L. for Linnæus; St. Hil. for Saint Hilaire. (DC.)

This rule has been followed by Linnæus, De Candolle, and all botanists up to a recent date. No particular rule has been laid down for the guidance of zoologists, but this will doubtless recommend itself to them when considered. In some later works, only those familiar with the literature can divine whether *Bth.* is the equivalent of Bentham, Benth or Booth, *Sz.* of Schultz, Steetz or Szowitz; or what is the equivalent of *Htsch., Hk., H. Bn., Bn., Btt., Lm., Reich. or Spng.*

Of Names to be preserved in writing, Dividing or Modifying the Limits of Existing Groups.

§ L. A change in the diagnostic characters, or a revision which carries with it the exclusion of certain elements of a group, or the inclusion of new elements, does not authorize the change of the name or names of a group.

§ LI. When a group or genus is divided into two or more groups, the original name must be preserved and given to one of the principal divisions. The division including the typical species of the primitive genus, if any type had been specified, or the oldest, best known or most characteristic of the species originally included when the primitive genus was first described by its author, is the portion for which the original name is to be preserved. If there is no section specially so distinguished, that which retains the larger number of species should retain the old name (DC.), but the latter cannot be applied to a restricted group containing none of the species referred to the primitive group by its author at the time when it was described or when he enumerated the species contained in it.

The majority of the replies to query XII of the circular concur in the above.

According to Linnæus the name should remain with the most common and officinal species; an equivocal expression if there is one which is most common and another the officinal species. The *Convolvulus spelum* and the *Erica vulgaris* were very common and very anciently named species when Brown made of one the genus *Calystegia* and De Candolle of the other, his genus *Calluna*. It was, however, much better to do this than to change the names of a hundred species of *Convolvulus*, and two hundred of *Erica*. When there is no authoritative type, the number of species should always be taken into consideration. (DC.)

§ LII. When an author has specified no type, it is then necessary, in dividing his genus, to retain his name for the subdivision containing the species, which the next subsequent author, treating of the genus, has specified or regarded as the typical exemplar. B. A. If no subsequent author has selected a type, the first species of the primitive author may frequently be taken as the type, or a species may be selected from among those originally specified as belonging to the genus when it was formed, due regard being paid to the necessity of retaining as many of the original species as possible in the division which is to retain the old name.

It would, manifestly, be liable to introduce errors and confusion, if it were insisted that the first species should invariably be taken as the type, or were it permitted to

take species subsequently added to the group, and which the original author did not know when he established his genus. No arbitrary rule will suffice to determine, off-hand, questions of so much complication as is often the decision in regard to the type of an ancient genus which has been studied by a number of authors.

In the first of the above cases lists are often arranged in alphabetical or faunistic order, or the aberrant species are placed at or near the beginning and end of the list, while the more generalized and characteristic species are put between the others. In the second case aberrant species might be added, and subsequently taken away from the genus, carrying with them the name consecrated by the primitive author to the very group which the subsequent reviser might then seize on for his own. Still more the aberrant species carrying the primitive generic name might subsequently be found to belong to a genus described before the one revised. Then the name originally given to a valid group might be subject to rejection as a synonym, while the valid group itself which originally bore that name was rejoicing under a new appellation received from the industrious revisers! Absurd as it may appear, mutations similar to this might be mentioned.

The answers received to questions on this point in the circular will be seen to be by a large majority in concurrence with this section.

§ LIII. In dividing a genus of which there are already synonyms, if these synonyms or any of them are typified by the same species or group of species as that or those originally selected as types for the primitive genus, the names should be cancelled *in toto*, and not used for the restricted subdivisions. (B. A.)

To use strictly equivalent synonyms, in a new sense for different divisions in one family, is sure to create confusion and necessitate lengthy discriminating passages in subsequent synonymical work. When the so-called synonyms are founded on species belonging to different sections of the genus, although the names may have been considered as co-extensive in their application, it is desirable to use these names to indicate the division of the genus when it may be revised. (B. A.) In fact there is hardly any difference between the latter case and the revival of a valid but forgotten name for the group properly designated by it, and to which another legal name cannot be applied.

§ LIV. In the case of the consolidation of two or more groups of the same nature the oldest name must be retained for the whole. If both or all are of the same date, the reviser may select the one to be retained. (B. A., DC.)

If a name of a genus be so defined as to be equal in extent to two or more previously published genera it must be cancelled *in toto*. (B. A.) Example. *Tritonium* Müller was so defined as to be equal to *Buccinum*, *Strombus* and *Murex*, of Linnæus. Hence it should be wholly rejected. *Psaracolius* Wagler is equivalent to five or six previously published genera, and must, therefore, be cancelled. (B. A.)

It follows from the above, that when it is necessary to unite several groups already named, the earliest unobjectionable name must be retained for the consolidated group with a modified diagnosis.

§ LV. When it is necessary to divide a nominal species into several species, the form which first received the old specific name is the one which should retain it. (DC., etc.)

§ LVI. When a section of a genus or a species is transferred to another genus in which a variety or other subdivision of a genus or species is already called by the same name as the group transferred, the group of

higher rank (as the species) retains the name while that of less value (as the variety) takes a new appellation. (DC.) Compare § LVII.

§ LVII. When a nominal genus is reduced to the rank of a subgenus or a group nominally of subgeneric value is erected into a genus; when a species becomes a subspecies or vice versa; their respective names remain unchanged, provided there do not result from it two genera or subgenera of the same name in the animal or vegetable kingdom, two species of the same name in one genus, or two subdivisions of a species of the same name in the same species. (DC.)

But in combining two groups previously considered as of equal rank, but of which thereafter one is to be subordinate to the other, the newest (or least widely known when both are of the same date) is the one to take subordinate rank; on the principle set forth in § LIV.

Of a starting point for Binomial Nomenclature.

§ LVIII. The scientific study of different groups, having a value greater than or equal to that of a class (classis), having been begun at different epochs, and the inception of that study in each group respectively being usually due to some "epoch-making" work, the students of each of the respective groups as above limited may properly unite in adopting the date of such works as the starting point in nomenclature for the particular class to which it refers: *Provided*,— that (1), specific names shall in no case antedate the promulgation of the Linnæan rules (Philosophia botanica, 1751); that (2), until formal notice by publication, of the decision of such associated specialists (in such manner as may be by them determined upon), shall be decisively promulgated, the adoption of the epoch or starting point recommended by the committee of the British Association in 1842, namely, the twelfth edition of the *Systema Naturæ* of Linnæus (1766), shall be taken as the established epoch for all zoological nomenclature. Lastly, that (3), when the determination of the epoch for any particular group, as above, shall have been made, the decision shall be held to affect that group alone, the British Association date holding good for all other groups until the decision for each particular case shall have been made by the Naturalists interested in it, upon its own merits. (Cf. Lec., ¶ 1, p. 203, et. seq.)

Recommended by the Reporter for adoption.

The question at issue is one upon which naturalists are unfortunately much divided in opinion, and the difficulties arising from this diversity are becoming more injurious to science with each succeeding year.

The decision is, of course, of fundamental importance in many branches of zoology. In order that the question may be better understood, a brief historical statement is subjoined.

A series of rules for nomenclature was to some extent foreshadowed by Linnæus in his *Fundamenta Entomologia* of 1736. These rules were first definitively proposed in the *Philosophica Botanica*, which appeared in 1751. These rules, however, related almost exclusively to the generic name or *nomen genericum*. In 1745 he had employed for a few species of plants for the first time a specific name (*nomen triviale*) composed of one

word. In contradistinction to the polynomial description of a species (*nomen specificum*) which was previously the rule among naturalists. That which now seems the most happy and important of the Linnæan ideas, the restriction of the specific name as now understood, seems to have been for a long time only an accessory matter to him, as the *nomina trivialia* are barely mentioned in his rules up to 1765.

In 1753, in the *Incrementa botanica*, while expatiating on the reforms which he had introduced into the science, he does not even mention the binomial nomenclature. In the *Systema Naturæ*, Ed. X, 1758, for the first time the binomial system is consistently applied to *all* classes of organisms (though it had been partially adopted by him as early as 1745), and hence many naturalists have regarded the Xth edition as forming the most natural starting point. The system being of slow and intermittent growth, even with its originator, an arbitrary starting point is necessary. In the XIIth edition (1766–68) numerous changes and reforms were instituted, and a number of his earlier specific names were arbitrarily changed. In fact, Linnæus never seems to have regarded specific names as subject to his rules.

It must be observed that an apparent rather than real distinction has been observed, especially by botanists, between the citation of the *authority* for names of genera and that relating to specific names. In the early part of the eighteenth century a few botanists, among whom Tournefort (Rei Herbar. 1719) may be particularly mentioned, had progressed so far as to recognize and name under the title of genera, groups corresponding in most essentials to the modern idea of genera. Linnæus himself adopted a number of these, and used the names of Tournefort and others as authorities after the generic name as adopted by himself. In this the great Swede has been almost unanimously followed by botanists, though the names take date only from the time of their adoption by Linnæus.

A very few authors, Bentham being the most prominent, have refused to cite any one except Linnæus as authority for such genera.

Whether the course of the majority be considered judicious or not, it is now the accepted usage in Botany. As regards names in general, botanists appear to agree in adopting the date of the Linnæan *Species Plantarum* (1753), as the epoch from which their nomenclature must begin. This work contains the first instance of the consistent use of the *nomen triviale*, subsequent to the proposition of the rules in the *Philosophia Botanica*, to which modern nomenclature is due.

Binomial designations cannot, of course, be reasonably claimed to antedate the period when binomial nomenclature, in a scientific sense, was invented, and in spite of the solitary instance of 1745, no good reason appears for extending the range of scientific nomenclature to an earlier date than 1751.

In 1842, the committee of the British Association reported "it is clear that as far as species are concerned we ought not to attempt to carry back the principle of priority beyond the date of the twelfth edition of the *Systema Naturæ*. Previous to that period, naturalists were wont to indicate species not by a name comprised in one word, but by a definition which occupied a sentence, the extreme verbosity of which method was productive of great inconvenience. It is true that one word sometimes sufficed for the definition of a species, but these rare cases were only binomial by accident, and not by principle, and ought not, therefore, in any instance, to supersede the binomial designations imposed by Linnæus." This related solely to zoology.

It is said that in the original draft of the report, the number of the edition of the *Systema Naturæ* was left blank, and afterward filled up by the insertion of "twelfth." This insertion renders the paragraph, otherwise judicious and accurate, glaringly incorrect. What motive resulted in the selection of the twelfth edition as opposed to the tenth, or of any special edition after the adoption of the binomial form by Linnæus, has never been set forth in a satisfactory manner. If any special edition were chosen, the tenth has *prima facie* claims for first consideration. It is as clearly binomial as any, and it is as consistently so. The inference from the paragraph as it stands, that the *Mus. Tessinianum*, the tenth and eleventh editions of the *Systema*, the writings of Pallas, etc., were only accidentally binomial, is too preposterous not to create a reaction against the committee's recommendation in the mind of any one familiar with these

works. This has been the result, in fact, and, to a considerable extent, in the works of the naturalists of northern Europe, the tenth edition has been taken as the starting point.

The rule following the paragraph quoted from the committee's report, however, contains no reference to any special edition or work, and reads, simply:—"the binomial nomenclature having originated with Linnæus, the law of priority in respect of that nomenclature, is not to extend to the writings of antecedent authors." (§2, p. 10, l. c.)

There is nothing to object to in this, and it is in all respects reasonable and fair. In adopting the tenth edition as a starting point, therefore, naturalists have not infringed on any of the original B. A. rules, but, at most, disregarded a subsidiary recommendation founded on an inaccuracy.

In 1863, however, the Association determined to overhaul the rules, and the amended ones adopted in 1865 contain the following remarks and modification of the second rule:

"The Committee are of opinion, after much deliberation, that the twelfth edition of the *Systema Naturæ*, is that to which the limit of time should apply, viz., 1766. But, as the works of Artedi and Scopoli have already been extensively used by Ichthyologists and Entomologists, it is recommended that the names contained in or used from these authors should not be affected by this provision. This is particularly requisite as regards the generic names of Artedi, afterwards used by Linnæus himself."

The original rule of 1842 is then modified (by the additions indicated in italics) to read as follows:

"The binomial nomenclature having originated with Linnæus, the law of priority, in respect of that nomenclature, is not to extend to the writings of antecedent authors *and, therefore* (sic), *specific names published before* 1766 *cannot be used to the prejudice of names published since that date.*"

It would appear that the Committee were "plus saint que le Pape," since they would reject names that Linnæus himself was ready to and did adopt. In this connection, Prof. Verrill (Am. Journ. Sci. and Arts, July, 1869) has made some judicious remarks calling attention to the works of Pallas, and Thorell has done the same for Clerck on the subject of spiders.

An apologetic paragraph, following the remarks above quoted from the B. A. Committee report for 1865, inferentially admits the error of 1842, but goes on and reaffirms it on the ground that confusion would otherwise result.

It is very doubtful if much confusion would be caused by leaving the question open, since half the naturalists of Europe and America have already adopted the tenth edition of their own motion, and the other half, or a large portion of them may not unreasonably be believed to be only held back from joining the others by a desire to conform to the rules, even where injudiciously framed.

In a large part of zoology, the change would make no difference whatever, since the scientific study of such branches has begun since 1766.

The principle embodied in the Rule now submitted by your Reporter, is inferentially admitted to be valid by the B. A. committee in their remarks on Artedi and Scopoli.

Since 1865, Thorell, in his monograph of European spiders, has boldly adopted, so far as specific names[1] are concerned, a plan similar to that here recommended, and takes the binomial work of Clerck (1757) on Swedish Spiders as his "epoch maker."

Geo. R. Gray, in his "Genera of Birds," adopts the first edition of the *Systema* (1735) much in the botanical sense as the epoch-maker for ornithological genera. For specific names he does not go behind the tenth edition (1758).

Alex. Agassiz, also, while declining to be bound by any arbitrary rules, has gone to the foundation of things in Echinological literature, and, from the typical specimens of their describers, has brought into scientific nomenclature the ancient and earliest names of Klein and others, whose work in this branch of zoology he pronounces far in advance of their time.

However inadvisable such changes would be in any department where the nomenclature may be tolerably well fixed; in those in which students are overwhelmed by

[1] The genera of spiders are not affected by the question.

the mass of undigested synonymy, as in Conchology and Entomology, it cannot be doubted that such work thoroughly and accurately done would be a vast relief.

For this reason I cannot but be impressed with the value which the compromise here suggested might have for various branches of zoology, should specialists look upon it favorably. It has already been suggested, with favorable comments by Dr. Leconte, that such a course should be pursued, and the suggestion has been carried still further in the rules presented for consideration to American entomologists, by Messrs. Leconte, Riley and Saunders.

Those departments having a tolerably well settled nomenclature, whether trembling in anticipation of sweeping innovations or not, would thus have it in their power to settle the matter once for all, and in the interest of the convenience of all concerned. Once settled, the subsidiary rectifications would be a matter of time.

It may be enquired, why, after criticising adversely the selections of the twelfth edition as a starting point, it is still recommended for retention in the event of specialists failing to agree on any other basis.

The reasons are,— 1st, because it has twice been recommended by the British Association committee, thus acquiring a certain status, and change is always undesirable unless it goes to the root of a matter and in a way to receive general assent; and 2nd, because in one of the branches most concerned in the settlement of the whole question, it appears for the stability of its nomenclature, to be a vital point that the usage founded on the B. A. rules should be maintained if possible; at least until the students of that branch (Entomology) shall decide on an epoch for themselves.

If it be insisted, in accordance with the old method that but one epoch shall be considered for all zoological nomenclature, it appears to the Reporter that the date of the tenth edition of the *Systema Naturæ* should be taken without regard to changes necessitated thereby.

More than half the replies to the circular are in favor of this starting point or one even earlier, the botanists of course insisting, in behalf of their department, on 1753.

§ LIX. In botany the epoch for scientific names is 1753, the date of the Species Plantarum of Linnæus.

The epochs chosen by Thorell for Spiders, and Agassiz for Echini, have already been alluded to.

Of Synonyms and Works subject to Citation.

§ LX. It is advisable in preparing tables of synonymy of a monographic character, to divide the citations into several groups according to their nature, the several citations in each group following each other in the order of their dates (which should always be specified) beginning with the earliest.

All synonymy is of an historical nature but may be divided into two groups of which one is strictly historical and the other biological. The historical series includes the citation of all authors who may have mentioned the organism and primarily exhibits the fluctuations of its nomenclature. It is divisible into two sections:—

1. *Pre-Linnæan* or *Bibliographical*, including citations of names in works antecedent to the epoch adopted for the starting point of the nomenclature of the class to which the organism belongs.

2. *Binomial*, containing citations of names from works in which the scientific nomenclature has been adopted.

The biological series contain citations of works in which additions

have been made to our knowledge of the organization, development, distribution or genetic relations of the organism concerned.

While the *names* used in the biological series may properly be cited in the historical series, authors of monographs may greatly facilitate the investigations of students by appending to their historical synonymy a biological list, especially, if, in the latter, they add to the citations of the papers or publications themselves, a word or two in parentheses indicating the character of the additions to knowledge to be found in the respective works, — as (Embryology), (Geogr. Distr.), etc.

The advantages of this course are sufficiently obvious.

§ LXI. Synonymy, properly speaking, has reference only to names coming under the second section of the historical series. Its object is solely the sifting of the nomenclature of an organism or group of organisms, that the name or combination of names which are entitled to be permanently connected with it, and by which it shall be denominated in scientific literature, may be definitely determined.

The object of citations in the biological series is of a different character. They are intended to serve as a guide to the student in researches of a biological nature as an index to the progress of investigation, and to the views on the subject held by different authorities. As such, the series should be disembarrassed from extraneous, purely synonymical citations. This distinction, especially noted by A. Agassiz, has hitherto been much neglected.

§ LXII. The following kinds of works are entitled to citation in bibliography, but not in synonymy.

1. Works antecedent to the nomenclature-epoch adopted for the class of organisms concerned.
2. Works subsequent to that epoch in which the binomial nomenclature is not consistently adopted.
3. Works not published.

Works of the first and second kind may often be advantageously consulted for biological information and cited in the biological series; as, for instance, Poli, who adopted a singular quadrinomial form of nomenclature, but to whom are due many important anatomical researches. No injustice is done by citing an author for the real benefit he has conferred on science, while declining to burden the latter with an incompatible nomenclature.

With regard to the works of the second kind much diversity of opinion has been expressed. Some naturalists would accept in synonymy, accidental binomial phrases, as entitled to priority as names, provided they occur in works published subsequently to the nomenclature-epoch. But in this, as in all cases when tested by fundamental principles, it is easy to arrive at a conclusion.

When one word at the commencement of a descriptive sentence or phrase is in italics or separated by a comma from what follows (as was the usual practice amongst ancient writers), it is a matter subject to a diversity of opinions as to whether this, together with the generic name if any were employed, forms a tenable binomial name or not. Some authors would adopt the genus and consider that no tenable specific name had been employed. Others would adopt both. Others again would reject both. But the question as to whether the author in the work referred to adopted and consistently used the binomial system of nomenclature is one upon which no difference of opinion can exist. It is a question capable of a categorical answer at once. Hence it would seem preferable to stand, once for all, on the solid ground of certainty and avoid a course which will inevitably introduce a large amount of uncertainty. This course is

that recommended by the B. A. Rules and already adopted by a majority of naturalists.

It may seem superfluous to object to works of the third category. But beside several MSS preserved in Museum libraries and sometimes quoted, though never printed, there are a few works which have been printed but never published. This is the case with a Museum Catalogue prepared by Link about 1806.

It was printed and contained a host of new names. But whether the author was ashamed of his work, or the authorities of the University declined to be sponsors for the innovations, the work was never offered for sale, distributed, or advertised by the author.

Only one copy is definitely known to have escaped from the University cellars, and it has been stated that the remainder, or most of them, were destroyed by fire. Yet in 1851, the solitary copy having been discovered, one or two authors called attention to it and demanded that these names should take precedence of those of Lamarck and others, which had been in use for nearly half a century. A few writers have adopted this suggestion, and in one branch of science at least, deplorable confusion has resulted.

The auctioneer's catalogue of Bolten's collection printed in 1798, but fortunately containing no diagnoses, and of which only one or two copies are known, falls nearly in the same category. A reprint was made in 1819 but is also one of the rarest of books.

§ LXIII. To avoid increasing the difficulties encountered in dealing with the already enormous mass of scientific names, authors are earnestly recommended to take the following precautions in publication.

1. To publish matter containing descriptions of new groups or species in the regularly appearing proceedings of some well established scientific society, or in some scientific serial of acknowledged standing and permanence.

2. If a separate publication or independent work be issued by any author, copies should at once be sent to the principal learned societies, scientific libraries and especially to those persons or associations known to be engaged in the publication of bibliographical records or annual reviews of scientific progress.[2]

The work should also be placed at the disposition of the scientific world by an advertisement of copies placed in the hands of some firm, society or individual, for sale or distribution.

3. To avoid most carefully the publication of new names or changes of nomenclature in newspapers; serials not of a scientific nature or of limited circulation; in the occasional pamphlet issues by weak, torpid or obscure associations which are distributed only to members or not at all: and in brief lists, catalogues or pamphlets independently issued, insufficiently distributed or not to be found on sale.

The question of the restriction of the nature of the channels through which additions to, or changes in nomenclature may be made, so as to exclude from consideration in synonymy such publications as do not conform to the proposed restrictions, has frequently been mooted. It was touched on in your Reporter's circular (XXV, XXVI) but the replies were almost unanimously to the effect that however desirable it may be, the plan is impracticable; a judgment in which the Reporter, with some reluctance, feels obliged to concur.

It is clearly, however, the duty of every publishing author to concur as far as pos-

[2] This can at present easily be done with hardly any expense, in this country through the Smithsonian Institution and its agents.

sible in the suppression of methods leading to confusion. The above recommendations are intended to lead toward this result. In the era of numerous serials of high scientific standing as well as learned societies established on a permanent basis, there does not seem to be any good reason for failing to comply with such regulations as may be best fitted to advance the convenience and best interests of all.

§ LXIV. The majority of naturalists interested in the study of any special class of organisms may properly unite in expressing an opinion in regard to any particular work treating of those organisms, in regard to the sufficient publication of which, at a certain date, doubts may exist; as to whether said work be entitled to be quoted in synonymy as well as in historical and biological bibliography.

It is, therefore, recommended, that in such cases should a decisive expression of opinion seem necessary or desirable for the benefit of science; — 1st, that due notice of the proposed action be previously given to those interested; 2nd, that when the action has been had that the results should be as widely published as possible; 3rd, that the decision of the majority, once made, be concurred in cheerfully by all the naturalists interested for the common good.

Almost every department of zoology, within the last twenty-five years, has suffered from the discovery of some utterly forgotten work, in which names had been applied to objects subsequently made known to the scientific world under other appellations which latter have been generally adopted. Such obsolete works are generally of no intrinsic scientific value, and are only recalled to public notice by the action of the *lex prioritatis* on the names they may contain. Even when at the time of their production they formed an advance on the knowledge of that day, it is inevitably the case at present that this advance is immensely behind the present state of the science, so that while the restoration of the obsolete names is in accordance with the principles which rightfully govern nomenclature, the effect upon biological study (of which nomenclature is only one of the conveniences), is positively harmful. Names sanctioned by years of usage, common to the whole literature, having a traditional as well as a present value, and standing for certain verified conclusions, are replaced by unfamiliar terms, which are perhaps conceived in error, foreign to modern scientific literature, and too often requiring the transposition of other, and familiar names from groups in connection with which they are universally known perhaps to groups equally well known under some other name, thereby producing the most lamentable confusion.

It is evident that the utmost care must be taken in dealing with the subject, since any general rule intended to arbitrarily discriminate, would be only too liable to react injuriously on other portions of nomenclature, in a way to make the justice of the rule questionable, bring its authors and supporters into disrepute, and, by failing to induce uniformity, to aggravate the difficulty it was intended to overcome.

Many naturalists have given much thought to the subject and various propositions have been suggested as a remedy. One of these which seems most reasonable, and which a number of naturalists agree in supporting, is to the effect that a name which has not been in use for (say) twenty-five years, shall be excluded from use thereafter in that special connection, as by a statute of limitations. (Riley, Lec.) Others, as Mr. Lewis, desire that only such names as are actually "in use" at a certain period shall be retained.

The objection to the first method is that it is arbitrary, that it will not necessarily produce permanency (for some other work just within the limit of time may turn up and reverse the decisions founded on the supposition that a certain name had not been "in use" within the period), and especially, as also in the second case, that " the term "in use" is not susceptible of an exact definition. The proposition of a name by an author may or may not cause it to be "in use". It may be overlooked or rejected by

others, or without for some time appearing in any other publication, it may be in very general use in letters, museum labels, etc. Everybody who is guided in his work by the particular views of the author referred to, in one sense "uses" the name though he may never publish it on his own account. No one can ever be sure that a contemporary name, even if glaringly erroneous, may not be (by the ignorance or error of some provincial naturalist) accepted in various obscure publications.

Hence it would appear that these propositions are impracticable, and this is the opinion of a very large number of the American naturalists who replied to the circular in which the question was submitted to them (XXI, XXII).

The only other resource would then appear to be either (1), the publication of a list of names in any special group with their types, which all the specialists of that group would agree to accept, or (2), some such course as the one suggested by the foregoing § LXIV.

The first is clearly impracticable, since perfection in nomenclature, as in other things, is a relative term, and but a small proportion of the names could be settled with certainty, from the constant progress of our knowledge of the relations of organisms.

The second seems to be the only practicable method. The difficulties which all naturalists deplore, in the main arise, in each specialty, from some one or two obnoxious works. The course proposed by Alfred Wallace (Trans. Entom. Soc., London, 1871, LXVIII), recommended by Dr. LeConte (p. 210), and acted on in the "Rules to be submitted", etc., of Messrs. LeConte, Saunders, and Riley (¶ IV), in respect of this particular case, seems, to your Reporter to indicate the proper method of cutting the Gordian knot and to be well worthy of consideration.

It should, however, be clearly borne in mind that this process is one that requires the greatest impartiality and delicacy in its application, and can only be justified by paramount necessity in any particular case. It is not in consonance with some of the general principles of nomenclature, can only be accepted when applied with self-evident propriety, and any license or abuse of the power it implies would react against the authors and make the last state of the science worse than the first.

Of Names to be Rejected, Changed, or Modified.

§ LXV. A name cannot be changed under the pretext that it is badly chosen, that it is not agreeable, that another is better or more widely known, that it is not of a sufficiently pure Latin derivation, or for any other contestable or valueless motive. (DC.)

§ LXVI. A name should be rejected under the following circumstances:

1. When this name has previously been applied in a tenable manner to another valid group of organisms in the same kingdom. (DC., Lec., B. A.)

2. When it is already applied to another species in the same genus, or to another subdivision of a species in the same species. (DC., B. A.)

3. When it expresses an attribute or character positively false in the majority or the whole of the group in question, as in cases (among others) when a name has been founded on a monstrous, abnormal, immature, artificial or mutilated specimen; or when a geographical specific name is that of a country entirely removed from the faunal or floral grand division to which the species belongs. (DC., B. A., Th., V., Bourg.)

4. When it is formed of two words belonging to different languages, as *eu* put before a Latin name, *sub* before a Greek name, *oides*, *opsis*, suffixed to a Latin name, etc. (DC., Th., etc.)

5. When it is contrary to the provisions of §§ L - LIX.

6. When it was published in a work not entitled *a priori* to be cited in synonymy (§ LXII), or which has been definitely excluded from synonymy by such action as is suggested in § LXIV.

7. When it outrages decency or religion. (Lec. 202, ¶ 5.)

It has happened that persons of scientific acquirements but of unbalanced mind or depraved taste have applied grossly indecent or blasphemous names to sundry organisms. It would seem as if a more thorough punishment could hardly be devised than the permanent attachment of their names as authority to the appellations referred to. But, since these names would remain a stigma on science as well as on their originators, and would outrage the feelings of a majority of naturalists, it is probably better that they should be suppressed. A few old names, originally in bad taste, have become so identified with the organisms they indicate, as to have ceased to be seriously offensive, and, being consecrated by usage, need not be disturbed.

8. When the name has never been defined, and a properly defined name has subsequently been applied to the same group, the earlier name should be rejected.

If the earlier name be known to the describer he will do well to define and adopt it when it will be accredited to him as authority, thus saving a synonym, but when this course has not been adopted it is too late to establish the undefined name.

9. When a name belonging to the Latin or to a modern language, and having an unquestionable and specific signification, is applied to a group which it cannot by its etymology properly indicate it must be rejected. (Th.)

Thus *Tarantula* Fabricius (1793), not being the historic tarentula is properly rejected for the later *Phrynus* Oliv., and the former name is applied to the true tarentula of the ancients. (Th.) But if another name had been the first applied to the true tarentula, in scientific nomenclature it could not have been suppressed to revive the classical name. There are very few instances where the species can be identified with sufficient certainty to justify the rejection of a name on the above ground as held by Thorell.

10. When a name is identical, when properly spelled according to a derivation given by its author, with a prior valid name in the same kingdom, it must be rejected. (Th.)

This is sufficiently obvious.

§ LXVII. When a name has been used in one kingdom subsequent to 1842, it should thenceforth be ineligible for use in the same kingdom except within the same order (ordo) in which it was originally applied.

It would be better for Science if all names which have once been used should thereafter be ineligible in the same kingdom. (Th., Bd.)

But previously to the promulgation of the B. A. rules little intercourse existed between the naturalists of different countries compared with what now obtains. So it has happened that the same name has been used several times for different groups, and in some of these cases being certainly invalid, has been applied to the first valid group for which it had been proposed. In this manner it may have come into general use and to reject such names in some cases would cause confusion.

It may, therefore, be considered as too late to propose a radical change, though by Baird, in ornithology, and others, this principle has been carried to its conclusions. But for more modern names the adoption of some such method seems urgently called for.

It might, at first sight, seem as if the reverse of the rule proposed would be desirable, i. e., that the name, if used again at all, should be valid only in *another* order than that in which it was first proposed. But, in the great multiplication of genera brought about in recent years, many are necessarily tentative, and depend for their adoption on the judgment of the best authorities for the particular order. Some may hold a genus valid, others reject it. It is not reasonable that students of one group should be kept waiting until a definite decision is arrived at (even if that were possible) in another group with which they are not familiar, and until the students of the latter group have decided whether to adopt or reject a name which has been used in both orders. (Scudd.)

Shall the student of Brachiopods wait until the Dipterologist shall decide the value of Robineau Desvoidy's genus *Megerlia*, before the former shall be able to adopt or definitely reject *Megerlia* of King? It has not been done in forty-five years, and *Megerlia*, King, is still in the limbo of names without a clear title. This is undesirable and wrong. Let the student of flies decide for himself whether he can retain Desvoidy's name or not, but let the mere fact that it has been used in a different class (classis) enable the student of brachiopods to reject it, and place his own terminology on a sound foundation.

Upon the validity of the genus *Pelagia*, Peron and Lesueur depends the right to exist of eight or nine other generic names in different classes. By the method usually tolerated, these questions can never be settled. Let all, except the student of Acalephs, then, have the right to wipe out the name, *Pelagia*.

It would be vastly better if this principle could be applied to all names; but it will be at least a partial and important relief to be permitted to apply it to those of modern date.

§ LXVIII. When an inelegant combination has been the result of using for the name of a new genus, a name or a modification of a specific name borne by a species which is to be contained within the new genus, the fact is not a sufficient reason for rejecting the generic or changing the specific name. (L., Ag., Th., etc.)

This necessarily follows from § LXV, but it seems desirable definitely to state it.

The practice is objectionable on account of its producing tautological inelegance, and because it has resulted in the formation of a number of generic names of adjective form.

On the other hand, in connection with certain of the Linnæan and other ancient and universally known species, it had several very beneficial effects. It recalled the typical form for which the genus was constituted, and in many cases it might rightly be regarded rather as a change of rank than the creation of a new name. The ancient species (ex. *Voluta oliva* Lin., genus *Oliva* Brug.) often covered an assemblage of forms equivalent to a modern genus. A vast number of the old names were thus constituted by Linnæus, Lamarck, Cuvier, Agassiz, and the fathers of science.

Their practice was to replace the old specific name by a new one. This practice was reaffirmed by the B. A. committee in 1842, as follows: — "§ 13. A new specific name must be given to a species, when its old name has been adopted for a genus which includes that species." The usage was very properly condemned by the Committee, as its benefits do not extend to little known modern specific names, while the objections to it are as forcible as ever.

But in 1865 the Committee decided that the usage of a century must be reversed, and the following modified rule was the result.

"§ 13. A specific name must not be altered to use that name for the genus; where this has been already done the old specific name must be restored, and a new generic name given to prevent an inharmonious repetition."

This innovation, the sweeping character of which the Committee cannot have realized, if carried into effect would uproot hundreds of the generic names best known to science, and so familiar that the fact that they were originally specific names has been

almost totally forgotten. Its spirit is opposed to the fundamental principles of nomenclature, and the end to be gained is of the most trivial character. The gain in elegance is not apparent in the substitution of *Crassirenus* (!) for *Mercenaria*, or *Tottenana* (!!) for *Gemma*, as generic names. But a few naturalists have followed the new method, and the replies to a question (XI) on the subject included in your Reporter's circular have been practically unanimous in favor of the rule as here stated.

In cases where the specific name was changed by the author of the genus and has come into general use, no good end will be gained by attempting to revert to the now forgotten original specific name. The retention of the latter is recommended merely for such cases as have given rise to controversy, or where the substituted specific name has not come into use. It is a singular fact that several of the more glaring instances cited as examples of inelegance by those in favor of the innovation show, when investigated, that the circumstances have not been understood. Thus, the original generic name of *Gemma*[3] *gemma* Deshayes was not *Gemma*, and neither the generic nor the specific name of *Guri gari* Schumacher is tenable; since the first is improperly formed and should be *Guria*, while the latter was applied by Rumph. a non-binomial author, and is a vernacular and not a Latin or latinized term. But in this, as in other cases, the usage of a hundred years and the fixity of nomenclature will outweigh any consideration of mere elegance.

Of Changes of Names.

§ LXIX. An author has no rights in regard to the change or rejection of names of his own proposition, except those which are common to all naturalists, and authorized by the rules of nomenclature. (DC., Th.)

When a name has not come into use, and its originator proposes a change not contrary to the spirit of nomenclature, it may, out of courtesy, be adopted by others and by usage become justified, even when not directly authorized by the rules. But when such a change is in direct opposition to the rules it cannot be sustained. An author has the same rights, no more and no less than other naturalists, over names he himself has proposed. In effect publication is a fact which cannot be annulled. (DC.)

§ LXX. The name of a cohort, subcohort, family or subfamily, tribe or subtribe, should be changed when the genus, from whose name it is derived, is known to no longer form part of a group in question. (DC.)

§ LXXI. When a section or subsection of a genus, preserving its rank, is transferred to another genus in which there is already a subordinate group bearing the same title, the first mentioned name should be changed. (DC.)

§ LXXII. When a species is transferred from one genus to another, in which latter there is already a species of the same name, the newest of the two identical specific names should be replaced by its first tenable synonym, or by a wholly new specific name if there be no synonyms.

When a species has received a new name by reason of the existence of a prior valid species of the same name in the same genus, and this second specific name has become fixed by usage, it is not necessary in subsequent transfers to recur to the first rejected specific name, unless some beneficial end is to be attained.

[3] Possessing Deshayes original MSS., I am able to say that his name was *Gemmula* and not *Gemma*, which latter was a typographical error. He did not see the proofs.

To illustrate this by a supposititious example let us assume that *a Buccinum striatum* was described by Linnæus; that Lamarck subsequently described a *Buccinum striatum* whose name was changed by Wood, on account of the existence of the Linnæan species, to *B. rugosum*. *B. rugosum* is found to belong to the genus *Nassa*. Yet it is not imperatively necessary to change the name *Nassa rugosa* (Wood), to *N. striata* (Lam.), after it had come into use. But if there had been already a *Nassa rugosa*, even if of later date than Wood's description, it would then be better to reinstate the name *striata* Lam., and thus confine all the changes to one species instead of embroiling two.

§ LXXIII. When a subspecies, variety, or other subdivision of a species, is referred to another species, the name of the former should be changed, if the latter already contains a modification of the same rank or kind bearing the same name. (DC.)

§ LXXIV. When a group is transferred from that which contains it to another, and the first preserves its original rank, its name should be changed, if it becomes senseless, or an evident cause of error and confusion in the new situation in which it is placed. (DC.)

§ LXXV. In the preceding cases the name to be changed or rejected is to be replaced by the oldest valid name of the group concerned; or, if there be none, a new name should be created. (DC.)

§ LXXVI. Names of groups having higher than generic rank, may have their terminations modified to render them conformable to usage or the rules. (DC.)

§ LXXVII. When a name (1) stated by the author to be derived from certain Greek or Latin words exhibits a glaringly faulty construction; or (2) when its orthography is evidently erroneous; or (3) when a name taken from the name of a person has not been written according to the real orthography of his name; or (4) when a wrong gender has been attributed to a name by its termination, either by its not agreeing in gender with the genus to which it is referred, or from some internal inconsistency in the name itself: — Naturalists are authorized to correct the faulty name or the faulty termination, provided the name be not very ancient and universally received under the erroneous form. This authority, however, should be used with great reserve, particularly if the change will affect the first syllable, and above all the first letter of the erroneous name. (DC., Th., B. A.)

1. Some naturalists would leave unchanged all errors of construction, no matter how glaring, and correct only orthographical errors, but by far the greater number including the B. A. committee regard serious errors of both kinds as subject to reformation. Mongrels or compound mutilates are generally rejected (Th.) when they cannot be reformed. *Valenciennensis* Rousseau, intended for a generic name, has probably been changed to *Valenciennesia* by Fischer.

2. In latinizing Greek words there are certain rules of orthography which should never be departed from. (B. A.) Hence such names as *Aipucnemia, Zenophasia, Aglristrodon*, must, acording to the rules of etymology (see § LXXXIV), be written *Ægycnemia, Xenophasia, Ancistrodon* and have accordingly been changed.

3. For instance, *Mangilia* Risso, derived from the name of Mangili, an Italian naturalist, has been most generally written erroneously *Mangelia*.

But to change certain universally known names on account of erroneous orthography would be very inconvenient. For instance, in the Botanical Congress at Lon-

don, in 1866, it was proposed to modify the name *Cinchona*, on the ground that it was named after the Countess Cinchona, but the majority of the botanists present advised the continuance of the established usage.

Gundelia is very far from Gundelscheimer, but since the ancient botanists permitted this license and it has been consecrated by a hundred years of habitual use, why change it? The purists alone remember Gundelscheimer, and the name *Gundelia* has been accepted as an arbitrary name. In these questions it is necessary to bear in mind that the fixity of nomenclature is the interest of greatest importance, and that a naturalist has the right (under certain limitations) to construct a generic name in any manner whatever; for example, in a way which may resemble the name of a person. (DC.) Vernacular names will be hereafter considered.

4. Thus, a *Scalaria* named after Miss Turton is to be written *S. Turtonæ* and not *S. Turtoni*. Names of nymphs and goddesses are necessarily feminine, and when used as generic names their terminations and those of their adjective specific names must also be feminine. *Viviparus* Montfort is inconsistent with itself and must be written *Vivipara*.

To change the first syllable, above all the first letter, of a name, is inconvenient on account of the arrangement of indices, tables, catalogues and dictionaries in alphabetical order. It is very incommodious, for instance, that several generic names commencing with E have been altered to He, on account of the rough Greek accent. These names have to be sought for in two places in all the tables. The Greek accents varied according to the dialects; it is hard to see why naturalists should be more rigorous than the Greeks. (DC.)

Names of uncertain etymology should not be changed on etymological grounds. (Th.)

§ LXXVIII. Although names of persons are latinized and not adopted in a Greek form, no one is authorized to reject or change the name of a group, compounded from that of a person with the prefix *eu*, *oides* or *opsis*. It is sufficient that they are not of Latin origin, for it is, above all, necessary to avoid changing names, but a naturalist of taste will avoid the origination of such.

Some naturalists have amused themselves by applying to species names which are Latin puns on the names of persons. *Trochus faba* McGillivray, ostensibly named after Mr. Bean; *Fusus domœnovæ* Val., after M. Maison-neuve, are examples. These names, however absurd, should not be changed, for, with the motives of the author of a name, one has nothing to do, provided the result, considered in itself, is not seriously objectionable.

§ LXXIX. When the name of a person is used without the necessary latinization of the termination, unless it already possesses a form similar to that provided for under § XXII, it must be changed to conform to the rules.

Example: *Clausilia Mortillet*, Dumont, is properly *C. Mortilleti*. Some naturalists have even gone further, and proposed specific names composed of two words, the Christian and surnames of the person to whom the species was dedicated, and without latinization! Example: *Donacia Scipion Gras*, Mort, after M. Scipion Gras as distinguished from his brother, Albin Gras, for whom another species of *Donacia* was similarly designated. Such names are deplorable and cannot be accepted. (Bourg.)

§ LXXX. When a name is derived from a vernacular word it must be accepted in the form given to it by its original describer, even in cases where the orthography of the name has been insufficiently understood by the author, and has given rise to merited criticism. (DC.)

Vernacular names, above all, when taken from barbarous languages, are frequently uncertain, and the manner of writing them doubtful. When once the name has been adopted by science, it would be too easy to change it, if one professed a rigorous exactitude. (Cf. for exceptions, note 3, § LXXVII.) *Coffea*, for example, would become *Cavea*, *Covea*, *Cauffea*, etc., according to each person's idea of the orthography of the Arabic name. The same principle holds good in relation to species allied or distinct, but having in different localities the same vernacular name derived from some character common to them all. A naturalist fixes the name on some one of the species, no matter which; otherwise it would be continually contested or changed. (DC.)

§ LXXXI. Vernacular names (1) derived from classical names by a light modification, may, if unmistakable, be changed by subsequent authors, into their proper Latin forms, but are not entitled to priority if not so adopted before another name properly formed has been applied to the organism in question. (Rep.)

Vernacular names (2) not so derived have no standing in science, and if a classical term having the same meaning is subsequently applied to the same organism or group, its priority dates only from the time when this was done by some author, who is entitled to be cited as authority for the name. (B. A. Bourg.)

1. *Patelle viride* may be supposed to stand for *Patella viridis*, and, properly modified by courtesy, is liable to be accepted, if no latinized name precedes the change in time of application.

2. No one is obliged to suppose that, for instance, *Vis aguillée* represents *Terebra aculeata*, until some author applies the latter name to the mollusk in question. (Bourg.)

§ LXXXII. Vernacular names, especially when applied to genera and species, if not proper nouns or having already an accidental Latin form, should be changed to conform to the rules of Latin orthography. (B. A.)

A pernicious practice, of very old date, exists, of applying to species, names not only of barbarous origin, but without latinization, and totally destitute of euphony. These are chiefly the local appellation of some savage tribe for the organism designated.

Thus we have *Hyperoödon butzkopf*, Gray, *Balæna tschiekagliuk* and *B. agamachtschik* Pallas, etc. *Butzkopf* is an obscene name applied by the Dutch boers of South Africa to any species of whale, though supposed by Gray to be a local name for the species he indicated, and the two species of Pallas, with others of the same kind, are described from Kamchatka, where the names he used are unknown.

The practice has probably gone too far, so far as proper nouns are concerned, to admit of the total rejection of such names when they are known to apply to the particular species referred to (LXXX). But when these barbarisms are adjective in their nature, they are, on the principles herein before cited, subject to reformation as pointed out by the B. A. Committee. No naturalist of good taste would inflict such names, unmodified, upon science, and it would be far better if they were totally avoided.

Of the Names of Organisms in Modern Languages.

§ LXXXIII. Naturalists employ in modern languages scientific Latin names or those immediately derived from them in preference to names of other origin or kinds. They avoid using these latter, except when they are very widely known and clearly intelligible. All friends of science should oppose the coinage of new vernacular names not existing in any

language, at least when they are not derived from the scientific Latin name by means of some slight modification. (DC.)

It is desirable to continue the use of Latin for scientific descriptions, and still more for names. These, like proper names of persons, should be available in all languages. The public adopts them rapidly as a matter of habit, even when they are grotesque. No one objects to such names as *Fuchsia*, *Rhododendron*, etc., now common to all countries. For much stronger reasons, it is desirable to proscribe the fabrication of so-called "common names." The public to whom they are addressed finds no advantage in them, for they are new to it, not to be found in any dictionary, and the learner must also know the Latin name of which the new term is a synonym. To comprehend how confusing a multiplicity of "common" names would be, it is only necessary to suggest, for instance, the condition of the Post Office department, if each village had an absolutely different name in each language. (DC.)

The manufacturers of new "common" names occasionally make some amusing slips, as in the case of a recent attempt in England, when for several groups of animals which already possess well known and characteristic names in the vernacular, new "common names" were proposed.

Of the Latinization of names.

§ LXXXIV. Greek names are latinized by substituting for the Greek letters their Latin equivalents according to the following table. (Herrm., Th., B. A., etc.)

α	$= a;$	(βῆτα)	*Beta.*
β	$= b;$	(βραχίων)	*Brachium.*
γ	$= g;$	(γλῶσσα)	*Glossa.*
δ	$= d;$	(δίψάς)	*Dipsas.*
ε	$= e;$	(ὑαλέος)	*Hyalea*, not *Hyalaea.*
ζ	$= z;$	(ζίζυφον)	*Zizyphus, Zizyphinus.*
η	$= e;$	(πειρήνη)	*Pirena*, not *Pirina.*
η final	$= a;$	(πειρήνη)	*Pirena*, not *Pirene.*
ϑ, θ	$= th;$	(τηθύς)	*Tethys;* (θέτις) *Thetis.*
ι	$= i;$	(βαλιός)	*Balia*, not *Balea.*
$\varkappa$	$= c;$	(ἱππόκρήνη)	*Hippocrena*, not *Hippochrenes.*
λ	$= l;$	(φυλλίς)	*Phyllis.*
μ	$= m;$	(μέλας)	*Melas.*
ν	$= n;$	(πειρήνη)	*Pirena.*
ξ	$= x;$	(ξένος)	*Xenus, Xenophora.*
o, ω	$= o;$	(φορός)	*Phorus;* (πῶμα) *Poma.*
π	$= p;$	(ποταμός)	*Potamus.*
ρ	$= r;$	(πτερόν)	*Pterum.*

ρρ	= *rrh*;	(φυλλίρ-ροη)	*Phyllirrhoa*, not *Phyllirhoë*.
σ, ς	= *s*;	(γλωσσός)	*Glossus*.
τ	= *t*;	(πτερόν)	*Pterum*.
υ	= *y*;	(ὑβόλιθος)	*Hybolithus*, not *Hibolites*.
φ	= *ph*;	(φορός)	Phorus.
χ	= *ch*;	(κοχλίας)	*Cochlias*.
ψ	= *ps*;	(ψάμμος)	Psammus.
αι	= *ae*;	(λιμνᾶῖος)	*Limnaea*, not *Limnea*.
αυ	= *au*;	(γλαυκός)	*Glaucus*.
ει	= *e*;	(τείνω)	*Exotenobranchia*.
εῖ	= *i*;	(χεῖλος)	*Chilostoma*, not *Cheilostoma*.
ευ	= *eu*;	(εὖρυς)	Eurus.
ῳ, οι	= *oe*;	(ὄις, οἰκέω)	*Dioeca*, not *Dioica*.
ον final	= *um*;	(ἐφίππιον)	*Ephippium*, not *Ephippion*.
ος final	= *us*;	(ὀμφαλός)	*Euomphalus*, not *Euomphalos*.
ου	= *u*;	(λουτήριον)	*Luterium*, not *Lotorium*.
γγ	= *ng*;	(ἀγγαρεία)	*Angaria*.
γχ	= *nch*;	(ἄγχω στόμα)	*Anchistoma*, not *Angistoma*.
γκ	= *nc*;	(ἄγκιστρον)	*Ancistrodon*, not *Agkistrodon*.
ῥ	= *rh*;	(Ῥέα)	Rhea.
ἑ	= *h*;	(Ἑρμαία)	Hermaea, not *Ermaea*.

It may be remarked in concluding that, while the advances of philology have introduced reforms into the pronunciation and phonetic spelling of Latin words during recent times, these reforms cannot be allowed to affect words which, having obtained an entrance into nomenclature, have assumed, so to speak, an arbitrary character and signification. Otherwise new and annoying elements of confusion would be added, where there are already too many. The Latin of scientific nomenclature is, and must remain, essentially the Latin of the eighteenth century.

On International Scientific Service. By A. R. Grote, of Buffalo, N. Y.

Amid the constant progress of human affairs reflective minds are busy with the origin of things, and with the endeavor to shape the policy of the future in the light thrown on human actions by generalizations from the past. In the growth of moral and intellectual faculties, we can see plainly that the answer to the question of who is our neighbor is being extended beyond the narrow limits of self, tribe, family, or nation, until we have included other varieties of mankind in the definition. Nor, perhaps, shall we stop here, but the recognition of our right line of conduct with regard to lower animals may not be long escaped. Through our experience we have increased our knowledge, and this knowledge it is which has directed us in the past, and still points out to us the true conduct to pursue to the rest of the world.

Where our attitude in this respect is once *right* no force can bring us out of it, but ever men are found to be impelled by our example and their own consciences to a similar position with ourselves, and so society is gradually revolutionized. Those who, from a large estimate of conduct, are led to distrust intellectual progress may, in reality, be assured that the one cannot flourish where the other decays; and should feel themselves safe in aiding the advancement of knowledge to the extent of their individual influence.[1] The invention of printing marks the third and present epoch of general civilization, the first epoch being limited by the acquirement of articulate speech in the yet shapeless past, and the second by the production of phonetic characters at a time in the history of mankind which archæology is enabling us to fix more and more definitely.

The motor of civilization must always consist in an improvement of the machinery for the exchange of thought. For our whole

[1] For some observations on conduct and religion, I refer to a paper entitled: Protestanism and Science in the "*Evolution*" for July, 1877.

progress in this direction is the working of a *comparative civilization*. And in this view the terms Savagery, Barbarism, might well fall away as having been misused, and being liable to misuse, and expressing different values at different times with different peoples. With this classification of the growth of the human intellect to guide us, and with the recognition of the fact that we are gradually coming into closer contact with other peoples on the globe through our intellectual enterprise, the time seems near at hand when, by an *International Scientific Organization*, the efforts of the best scientific minds of the more civilized nations may be joined for the solution of those problems which all are alike forced to grapple with, and which of themselves constitute the sufficient proof of a larger kinship than is expressed by the political boundaries of the globe. The benefit which humanity has derived from the formation of local societies for the advancement of knowledge need not be rehearsed at this time. It is sufficient to say that they have proved admirable guides to the intelligence which produced them. The existing national associations, in this country and in Europe, are performing excellent work, but there are other questions to the answering of which their means are inadequate. Foremost among these there is that of the origin of our species. Indispensable to a correct habit of thought is the solution of this question, and its elucidation must be sought for in regions outside of those inhabited by the more civilized nations.[2] The various scientific explorations in Africa, Australasia, and the polar regions, need cooperative assistance to realize the best results from the outlays, while the new knowledge they bring is the common inheritance of all reading peoples. Justice then would require that where all participate, all should contribute. The plan of the *International Scientific Service* here provisionally proposed embraces the appointment of commissioners by the civil governments of the world, whose deliberations would be the wisdom of the age, and whose recommendations would be respected by the legislative powers of the consenting and represented nations.

Under their auspices all extra-limital, astronomical, geographical, and biological expeditions, would be fitted out, and directed to those places which would be more fruitful for the particular purpose.

[2] I would refer here to a paper "On the Peopling of America" read before the Buffalo Society of Natural Sciences in February, and reprinted in the "American Naturalist" for April, 1877.

No longer should we be subjected to failures arising directly or indirectly from national prejudices. The differences in the mental faculties between the different nations would prevent the loss in such a body of any possible suggestion the human intellect could afford.

From an economical point of view the outlay of the different governments for scientific explorations would be lessened, and more effective work would be done.

The amount to be contributed would be less because the expenses of any expedition to be decided upon by the Service would be made up by a quota from all the governments represented.

The tendency to enlarge our application of good conduct is destructive to a narrow national sentiment; this is a sentiment which is only laudable when it tends to preserve a high morality, and it is weaker where the intellect is more advanced. When science takes hold of the brotherhood of nations and calls upon them to undertake the solution of vital problems for the common good, there must surely be a glorious response. Of the existing sympathy between the nations we have many ready proofs. The Austrian Polar expedition is rescued by "foreigners," and America returns to England the ship she lost in northern ice. The flag of the International Scientific Service should be made neutral by treaty, and would be held sacred by all.

As tending to break down social prejudice, as working in a direction towards both greater economy and greater result, I venture to lay the proposition before this Association that it memorialize Congress to appoint Commissioners on the part of the United States, who would inaugurate the formation of such an International Scientific organization, and by resolutions to be passed by this Association request such action on the part of kindred scientific bodies in other lands as would influence their respective governments to assist in the enterprise.

It seems to me that some such step as I now speak of will eventually be taken. If the plan proposed be now acted upon, it will be at least a fitting thing that it was commenced by a country that protects the alien, and allows liberty to all its inhabitants to pursue their happiness. And it would be well for America to move in any matter that will create an active sympathy between the nations in scientific matters. For so will free institutions be the more readily preserved. Knowledge of itself brings a conduct that

must give at last tolerance and good will to all mankind. Obviously, then, any plan that will increase and diffuse our stock of experience should be adopted.

The course to be pursued by well balanced minds in handling questions as to the tendency of human conduct, seems plainly to be the cultivation of knowledge, so that we may get more light as to our proper behavior.

SECTION A,

MATHEMATICS, PHYSICS AND CHEMISTRY.

ADDRESS

OF

PROFESSOR EDWARD C. PICKERING,

VICE PRESIDENT, SECTION A.

Fellow Members of the Association—

Ladies and Gentlemen:—

It is a great disappointment to me that I am unable to address you this evening in person. But the heat and length of the journey warn me that it is safer to remain at home. I have looked forward for some time to this opportunity of calling the attention of the Association to a subject in which many of you are, I know, already much interested, the Endowment of Research. We all admit that this is one of the great objects of this Association, as of almost all scientific bodies. But what steps are we taking to aid this object, beyond looking on with interest while our members and others investigate various scientific problems, listening approvingly to the results, and publishing the papers? Doubtless it will be said, and with justice, that we cannot do more at present for lack of means. But the question I wish to raise lies deeper than this. Many persons admit that there are enough public-spirited and liberal men in the community to furnish the money needed for any object which can be shown to be really worthy. Let us for the moment admit this argument, let us assume that abundant means can be obtained, provided that assurance can be given that the result will justify the act. Not that the institution

shall be made self-supporting or return an income, but that the money shall not be wasted and the results shall be a continual increase of human knowledge, or improvement of the condition of the human race.

The first obstacle we encounter is the opinion widely maintained even by scientific men, that the original research of a country is a natural growth and that it is useless to try to force it. We might as well say that music and art are natural growths and that it is therefore useless to teach them! What should we have of ancient art were it not for the munificent encouragement of many ancient rulers? In later days how would literature and art have thrived had it not been for the support, often scanty it is true, of the public in purchasing books, paintings and sculpture? With the man of science it is quite different. There is generally little or no pecuniary reward for his success. The public do not eagerly crave each new memoir on the higher mathematics. A crowd does not gather around the bulletin board to read the discovery of a new asteroid or organic radical. The consequence is that since the man of science, like other men, must live, he is obliged to engage in some other occupation, generally teaching, which still allows him apparatus, a little time and generally less means, for research. Under these circumstances should we not be surprised, not that so little is accomplished, but rather that so much volunteer work is done? Can we doubt that far more would be accomplished if these same men were allowed to devote their entire energies to their investigations and were aided by the necessary appliances?

It is said that research is carried on by few and that but one man in a thousand is qualified for such work. But this is the strongest reason for making every effort to render the energy of such men most effective. The obvious solution is organization —carrying out a plan by which research should be rendered as systematic as are the processes of the mechanical arts. Suppose that a man should attempt to build and furnish his own house! He might devote his whole life to the work and still obtain a dwelling very inferior to what would be erected in a few months, by a small portion of that system which we call civilization. Suppose that he wished to travel, and should build his own boat or locomotive! To take a case more like that in question. Compare the old-fashioned watch where the maker was compelled to

make even the wheels himself, with the precision and uniformity of the chronometers of the present day. Notice also the result in scientific work where organization and division of labor have already been introduced. What would be the results of the Coast Survey if those who plan the work were obliged to erect the signals or take the soundings? At present an investigator is obliged to originate the subject, to plan the apparatus in detail and often even to construct it with his own hands. He must also be able to perform the experiment and discuss the results. It is no wonder that so many accomplishments are rarely united in one person. It would, on the other hand, be comparatively easy to find two or three persons who, between them, could divide these labors. Again, so much time is often spent in preparing the apparatus and making the preliminary observations that the college professor feels that he cannot afford to make the long-continued and oft-repeated experiments needed to bring his work to a proper conclusion. He, therefore, publishes a preliminary paper with the promise, seldom fulfilled, of completing it in the future. Let us take an actual example. Suppose the subject selected is the reflection of light. Much time and skill may be required to devise a suitable photometer and to bring it into proper working condition. When this is once done it is only necessary to find an assistant with good eyes who can repeat over and over the measurements of the light reflected by different substances at various angles of incidence. The work now becomes a simple routine, and if properly organized is not expensive. A large class of scientific work is of this kind. In fact most quantitative investigation, especially that serving to establish physical laws, requires oft-repeated measurements of the same quantity. An assistant will often thus obtain even better results than his superior, because his time being less valuable will be less occupied with other matters, and he will be able to concentrate his entire energies on his work. Moreover, an assistant may be selected with special reference to his work, as in the present case for the sensitiveness of his eye.

Before proceeding further let us consider how far the field is already occupied, and what aid is now offered in this country to research. This may be stated in very few words. We have first the munificent bequest of one of the first Presidents of this Asso-

ciation, who thus added at his death another to the long list of valuable contributions to science, to which his life was devoted. The income of the Bache fund amounts to two or three thousand dollars, and is expended in aiding scientific men in conducting original investigation. Secondly, the Rumford fund, although originally intended merely for giving medals for discoveries in light and heat, is now largely applied to aiding investigation in these sciences. The large income, considering the special nature of the subjects included, enables liberal aid to be extended to any worthy research in light or heat. The Smithsonian Institution, besides its many indirect aids to research, applies a portion of its income directly to this work. With these should be mentioned the Boyden premium, a sum of one thousand dollars offered for many years by the Franklin Institute for a specific investigation. I am informed, however, that no application for this reward has ever been made. The establishment by the Johns Hopkins University of Fellowships of which the incumbents are expected to devote their time mainly to research is an important step in the right direction. Many other colleges indirectly countenance or mildly encourage research, some actively, but most of them passively. Some persons, however, even go so far as to maintain that the time and energy of a college professor are paid for that he may teach, and regard original work as outside occupation. Were this view general, small indeed would be the growth of science in this country.

I shall confine my remarks to the sciences included in Section A, which is defined by Mathematics, Physics and Chemistry. Mathematics as here used includes in its applications too wide a field for any one person. It would probably be best to omit some portions. Astronomy, for instance, could be better treated at the Observatories now existing. Not that the wants of this science are as yet supplied, but we have already too many unsupported Observatories, and far more could be accomplished with half the number having double the endowment. Geodesy might also be left to the Coast Survey, were it not for the excellent field still open in topography. This is especially the case in connection with the State Surveys which will, doubtless, be established throughout the country as soon as the people are educated up to an appreciation of their value. I cannot forbear in this connec-

tion calling attention to the need of a Summer School of Topography, which might furnish valuable results, at the same time that it would give health and strength during the summer season. The problem of mountain surveying will well repay study, as there is at present no satisfactory solution. The best mountain contour maps are far from representing the actual surface of the ground. Under Mathematics should also be included Mensuration in its various branches and many portions of Engineering. The latter would be so closely allied to the work in Physics, in the subjects of Mechanics and Heat, that it would be difficult to draw the line between them. Every branch of Physics would be easily treated by this method, as in Mechanics, Sound, Light, Heat and Electricity, numerous problems are awaiting an experimental solution. The excellent results attained by students in many of our physical laboratories prove conclusively that assistants could be obtained capable of undertaking work of the greatest precision. Chemistry, besides its ordinary branches, should include the laws of molecular action, thermo-chemistry and the more difficult problems of animal and vegetable chemistry.

The working corps of an institution established for making researches in the subjects named above should be somewhat as follows: —

First, a President, who need not necessarily be an investigator, or even possess great scientific ability. He must have good executive ability, be a judge of men, and understand thoroughly the engineering principles of construction.

Secondly, a corps of investigators, men of acknowledged scientific ability, and selected for the originality of their ideas, even if they have not shown special skill in carrying them into practice. Three men to represent the subjects of Mathematics, Physics, and Chemistry, would be capable of carrying on an immense amount of research. Each should have one or two deputies or assistant professors, capable of taking their places during temporary absence. Their duties would be mainly planning details, superintending the construction of apparatus, and answering the questions of their subordinates.

Third, a large corps of assistants, whose duty it should be to carry out the work laid out for them, but who would not necessarily be able to plan it. They form the hands, while the preceding

class correspond to the head of our organization. Each investigator should be able to provide work for at least ten such assistants. They would generally work in pairs, one observing, the other recording, and would change places at intervals. Their work would be mainly routine, and would require care and mechanical, rather than intellectual, skill. Many young men would be glad to secure such work temporarily, though it would be permanent for few, as the salary would be low.

Fourth, workmen, such as a mechanician, carpenter, tinman, etc., capable of constructing in wood or metal the apparatus devised. One person should also be employed whose duty it would be to see that the apparatus was always ready for use. This would be especially important for the chronograph, telegraph wires, electric light and other appliances liable to be used by several persons.

The subjects for investigation in each department would in general originate with the professors in charge. They should also encourage their assistants to suggest subjects, and aid in planning them. Many other scientific men would, doubtless, avail themselves of an opportunity to have their theories tested when unable themselves to perform the necessary experimental work. The plan would in all cases be submitted to the President in writing, with an estimate of its cost, of the apparatus needed and of the probable time required to complete it. If found practicable and approved, the apparatus would be constructed or purchased, and tested under the direction of the professor by his more skilful assistants. When they were able to obtain accordant results, they would show one or two of the younger assistants precisely how the measurement should be made and carefully supervise their first trials. A long series of results could now be obtained at small expense, with slight supervision and direction as to the most important variations to be tried. The results would finally be reduced and prepared for publication.

Let me now invite you to accompany me on a visit to this supposed Institution, that we may examine its structure more in detail. We shall find it where land is not too valuable, but near enough to some large city that workmen of all kinds may be obtained at short notice. It is set back from the road so as to be free from dust and the jar of heavy vehicles, and commands a distant view in at least one direction. This may be needed for ex-

periments on atmospheric refraction or opacity, on the velocity of light or for many other purposes. A distant lighthouse forms an excellent object for such observations at night. Association with, or at least proximity to, some large college is much to be desired to avoid duplication of the collections of books and apparatus. Many college professors have under their charge a dozen instruments, each of which could profitably occupy the entire time of one person. These instruments are now simply exhibited to their classes once a year.

The building itself is large but low, and resembles one or more blocks of two-story dwelling houses. No more common mistake is made than in wasting the money which should be used for equipment, on architectural effect. This, although greatly desirable in itself, is often out of place in a building devoted to science, and in fact is not unfrequently the cause of serious inconvenience. The windows should be small, that they may be easily darkened by shutters, and the walls should not be too thick, or carry heavy mouldings or cornices, on account of the light. It is useless to hope for architectural beauty in this building, as the effect would be spoiled by attachments which might be made to the exterior. The rooms are numerous but most of them small, as only one or two persons would in general engage in the same research and one experiment would often disturb another. The President and Professors should all live under the same roof with their work, since it may often be necessary that they should be present at any hour of the day or night. Where an observation must be repeated at short intervals, inconvenient working hours must sometimes be maintained for a considerable time.

On entering the building we find that it is arranged like a hotel, with long entries running from one end to the other, and rooms leading off on each side. Two iron rails are laid on the lower entry and continued through a rear door in a straight line to some distance behind the building. By placing a car on them with one wheel graduated, as proposed by the Coast Survey, considerable distances may be measured with the greatest accuracy. These entries will have various other uses, as in photometry, in studying wave-motion, elasticity, resistance of pipes, etc. The cellars should be dry, properly finished and lighted. They would prove most useful for accurate measurements or other work requiring a

uniform temperature. They would also contain furnaces, and a small engine for furnishing power throughout the building. Stone piers disconnected with the floors would pass through the building for the support of delicate instruments. Many of these might be attached to a single pier. Numerous pipes are laid under the floors for carrying water, gas, oxygen, hydrogen, steam, compressed air, etc., to any desired point. Wires are also provided for transmitting electric currents. Batteries would be replaced by a magneto-electric machine driven by the engine which would thus enable the electric light to be supplied at a few minutes notice. Various auxiliary small motors, as turbines or gas engines, might also be desirable. Time would be transmitted electrically throughout the building, and a chronograph with several barrels would register observations in any portion of the building.

These examples serve to show the system of coöperation by which various appliances, which any investigator may need, might be rendered available for many. Any one who has engaged in such work will realize how much would be saved by having such means of measurement always ready for immediate use. Often nine-tenths of the time is spent in getting instruments ready which have not been used for months, or of which portions are used for other purposes.

I think no one will deny that the scheme here proposed would, if carried out successfully, greatly increase the original research of the country. It would act not only directly, but by stimulating those connected with other institutions. Doubtless, too, many amateurs would be ready to avail themselves of the facilities here collected and contribute to its support, the money that would thus be saved. Were it desirable to let it conform to the demands of applied science much useful work might be done by offering opportunities for testing new inventions or products. For example, the power and economy of new motors, the strength of new brands of steel or other metals could here be determined with accuracy and economy. The advantages of a corps of unprejudiced observers whose position would place them above the suspicion of partiality, would prove of great value in many cases. As experts in a legal case they would have the advantage of having at hand every appliance for proving the correctness of their statements. But apart from these practical applications, in the

realm of pure science no one can deny the value of the results likely to accrue. Not only could the more difficult problems be studied to better advantage, but those more formidable from their extent and now rarely undertaken by a single individual might easily be solved by coöperation. Now their only solution depends on an occasional Government appropriation where large portions are often lost wilfully, or spent ignorantly by the many hands through which the money passes, before it is brought to bear on the scientific conditions of the problem.

Let us now return for a moment to the question of endowment. It is well known that there is no country in the world where so much money is given by private individuals to the encouragement of education and science. Such persons, not unnaturally wishing to be associated with their gifts, have in many cases established colleges bearing their names. Let no man think that he will now benefit the cause of higher education by so doing. The demand is more than supplied. We have too many colleges with far too little endowment. Each new college seriously injures its neighbors by drawing pupils from them, and if insufficiently endowed no one can be expected to contribute to the glory of another man's name. The consequence is a struggle for existence on the part of what should be active literary institutions, extending, as well as disseminating, human knowledge. The same remarks apply to other literary or scientific institutions, as libraries, observatories, or museums of natural history. No benefit accrues to science from an observatory without a telescope, or from a telescope without an observer. The true patron of science will select an object proportionate to his gift. If he will abundantly endow any one subject, no matter how limited, he will confer a real boon on his fellow men.

Finally, the advantages of establishing the institution which I have described are that it opens a new and unoccupied field. It does not encroach on existing institutions, or in any way injure them. On the contrary, if associated with a college, it would prove a great benefit by the increased facilities which would thus be collected together, as furnishing instructive employment for a time to some of the graduates, and as increasing the scientific atmosphere of the place. It would benefit science by a constant extension of its boundaries, and if properly managed should be-

come the headquarters of experimental science in the country. That the details given above are defective and open to criticism I do not doubt, but that the object is laudable I presume no one will deny. Whoever will supply this want will leave the name of one who extended human knowledge and benefited his fellow men.

PAPERS READ.

ON AN ALLEGED ERROR IN LAPLACE'S THEORY OF THE TIDES. By J. G. BARNARD, U. S. Army.

IN a paper read before the American Association and printed in its Proceedings (Buffalo meeting, August, 1876), entitled "Some Remarks on the use and interpretation of particular integrals which 'satisfy' general differential equations expressive of dynamic problems, in cases where general integration is impossible: Suggested by Laplace's dynamic Theory of the Tides;" after remarking that the "particular integrals" of Laplace by which he expresses the tidal *rise* and *displacements* are all "wave" forms, which for the semi-diurnal tide are as follows:

$$a \begin{matrix} cos \\ or \\ sin \end{matrix} \left\{ 2\,nt + 2\,\omega + 2\,\psi \right\}$$

(in which a[1] is a function of the disturbing force and of the polar distance, θ), occurs the following passage with the appended foot-note:

"For the *semi-diurnal* tide the values of the coëfficient a are determinable for a continuous ocean of uniform depth, if the changes in right ascension, declination and distance, of the attracting bodies be disregarded, as also the density of the water in comparison with that of the earth. In that case the coëfficient a, for tidal elevation, has been developed by Laplace into a series.

$$(1) \qquad a = A^{(1)} \sin^2 \theta + A^{(2)} \sin^4 \theta + A^{(3)} \sin^6 \theta \ldots . \text{ etc.},$$

in which $A^{(1)}$ is the ratio of the semi-diurnal part of the disturbing force to gravity, *i.e.*

$$A^{(1)} = \frac{3L}{4\,r^3 g} \cos^2 \mathrm{v}$$

while $A^{(2)}$ is *in*determinate; and the remaining coëfficients $A^{(3)}$ $A^{(4)}$ etc., are determinate linear functions of these two, expressed by the equation

$$(2) \quad 0 = A^{(f+2)}\,(2f^2+6f) - A^{(f+1)}\,(2f^2+3f) + \frac{2\,n^2}{l\,g}\,A^{(f)}$$

[1] Printed K in former paper.

Taking the above value for $A^{(1)}$; retaining the symbol $A^{(2)}$ to represent *any* arbitrary value; determining by (2) the others in terms of these two, we should have an expression, in series, for the tidal rise, made up of *two* sets of terms one of which has for multiplier the disturbing (or tide-generating) force $A^{(1)}$ (which disappears if that force has no existence); the other has for multiplier the indeterminate or *arbitrary* quantity $A^{(2)}$—which set having no dependence upon a disturbing force, evidently expresses a peculiar *free wave* semi-diurnal in its phases, which, once put in motion (*i. e. initially* established), may exist, *resistances of friction, viscosity, etc., abstracted*, not only independently of the disturbing force but simultaneously and *cumulatively* with the 'forced wave' expressed by the terms in $A^{(1)}$. But this free wave 'is one of the oscillations which depend on the primitive state of the sea,' and which 'must quickly have disappeared by resistances of various kinds.' I, therefore, *omit* entirely all terms having $A^{(2)}$ as a coëfficient (which is equivalent to putting $A^{(2)} = 0$) etc., etc."

NOTE TO ABOVE.

"Mr. Airy has somewhat sharply criticised Laplace for the unwarranted inference that $A^{(2)}$ is subject to the law governing the succeeding coëfficients, expressed by the equation (2). I think the above remarks justify my partial concurrence. But Mr. Airy, retaining Laplace's developments (with $A^{(2)}$ thus determined; which only amounts to so much increase to the coëfficients of the arbitrary series which he adds), affirms that Laplace 'ought to have added to this series' the very terms which I *have omitted*, as expressing what Laplace, at the outset, in language I have twice quoted, *ruled out*. These remarks seem necessary to explain why I use an expression not only different from Laplace's, but also from Mr. Airy's correction. Mr. Airy remarks that, through the indeterminateness of $A^{(2)}$ the condition may be imposed that the meridional component of tidal motion be nothing for a prescribed latitude—*i. e.*, that "an east and west barrier following a parallel of latitude be erected in the sea;" or in other words that the ocean be bounded north and south of the equator by shores following certain parallels. This must be admitted; and *likewise* that *to accomplish it*, one of those 'quickly disappearing' *initial* oscillations (*i. e. free waves* having the $A^{(2)}$ coëfficients) is involved.

* * * * * * * * * * * *

One further remark may be made. The $A^{(2)}$ terms represent an absolutely 'free' wave, inasmuch as it can exist even though there be no semi-diurnal distorting force. They also represent an oscillation which when superimposed upon the 'forced' wave, the *two together* 'satisfy' the conditional equation (as the latter does singly). As in the case of the diurnal motion, this superimposed oscillation (absolutely arbitrary in the *magnitude* of its development) is neither generated nor *maintained* by the disturbing force. To the former, however, the external force is indispensable in order to suppress the strains which would mar the quasi-solidity of the water (and the *self*-maintenance of the motion); but the latter is absolutely independent of such force. I cannot doubt that I am right in my position that this latter would (through resistances) speedily

disappear and settle down to the dynamic 'equilibrium' expressed by the terms in $A^{(1)}$: in other words, the 'forced' wave alone : nor that, though it 'satisfies' the conditional equation, it should form no part of the solution, either in the disguised form in which Laplace has introduced it ; or in the explicit form given it by Mr. Airy."[2]

At the time of reading the above, and for nearly a year afterwards, I was unaware that the matter had previously been the subject of comment. The very able "Tidal Researches" of Mr. Wm. Ferrel (published by the U. S. Coast Survey in 1875) early received, but mislaid, had remained unexamined ;[3] while Sir William Thomson's paper in the Philosophical Magazine, September, 1875, "On an alleged error in Laplace's Theory of the Tides" did not come to my eye till quite recently. After quoting from Mr. Ferrel as follows :

"Laplace, however, failed to interpret correctly in this case his own solution, so that the numerical results which he has given for different assumed depths of the ocean are erroneous ; but still the general results just stated are readily seen from the solution. Having failed to see the indeterminate character of the problem, he adopted a singular and unwarranted principle for determining the value of a constant, which is entirely arbitrary in the case of no friction, but which vanishes in the case of friction, however small. This oversight of Laplace and the indeterminateness of this constant were subsequently pointed out by Airy ;" — Sir William makes the following comment :

"The 'singular and unwarranted principle' thus referred to, is in fact an exquisitely subtle method by which it seems Laplace had determined a constant which is not arbitrary in any case, and

[2] That, while the free wave will "speedily disappear," the theoretic "forced wave" will with equal speed, by action of the identical "resistances," be degraded into something wholly different which can be maintained by the tide-producing forces only in this degraded form, is obvious enough. Nevertheless, it is the logic, good or bad, of the method that the latter, in their pristine form, are accepted as the true tidal types while the former, having *no* self-maintaining power, are ruled out. And the logic is certainly good when it is only a question of free waves, non-synchronous with the tidal forces, and dissimilar in manifestation ; for such are wholly alien to tides ; while the theoretic forced wave may be regarded as our ideal conception of an actual tide ; or if the term is liked better as an *approximation* (even though it be *not* one). It is certainly less cogent, if there be, as stated above, a free wave not only synchronous with the forced tidal wave, but capable (resistances apart) of existing cumulatively with it ; *both* requiring *initial* establishment ; neither being compatible with resistances. But the doubt that then arises involves the method, rather than the logic.

[3] Mr. Ferrel anticipates my views in the words "But, except in the case of a perfect fluid without friction, the only value to be used is that of $A^{(4)}$ (Laplace's A) $(^{2}) = 0$, which makes the oscillation depend entirely on the distorting force and vanish with it."

which cannot be more than infinitesimally modified by infinitesimal friction."[4]

The expression (2), p. 73 (in which Laplace's own notation is used), may be put in the form:

$$(3) \qquad \frac{A^{(f+1)}}{A^{f}} = \frac{\frac{n^2 + lg}{f(f+3)}}{\frac{2f+3}{2f+6} - \frac{A^{(f+2)}}{A^{(f+1)}}}$$

The value of $\frac{A^{(f+2)}}{A^{(f+1)}}$ in the denominator may also be expressed by (3) (substituting throughout $f+1$ for f,) and then substituted in (3); by which $\frac{A^{(f+1)}}{A^{(f)}}$ will be expressed as a function of $\frac{A^{(f+3)}}{A^{(f+2)}}$. Continuing this process indefinitely we obtain the value of the first-named ratio as a "continued fraction." But to calculate its numerical value we must stop at some point, throwing away the final $\frac{A^{(f+n)}}{A^{(f+n-1)}}$ of the denominator; and this is equivalent to saying that for some large value of the index, f, $\frac{A^{(f+1)}}{A^{(f)}}$ *is zero; i. e.*, that the series of coëfficients $A^{(1)}$, $A^{(2)}$, $A^{(3)}$, etc., becomes rapidly convergent. The process amounts to determining *backwards* the successive values $\frac{A^{(f+1)}}{A^{(f)}}$, $\frac{A^{(f)}}{A^{(f-1)}}$, $\frac{A^{(f-1)}}{A^{(f-2)}}$ in terms of the most *remote ones*, assuming for some one of *these* a limiting value so nearly *zero* that it may be discarded; indeed, without this assumption, the fraction cannot, approximately even, be computed. Hence also the very first ratio $\frac{A^{(2)}}{A^{(1)}}$, must be determined by the use of this continued fraction; and *this* is the "exquisitely subtle method" of Thomson — the "mere sport with symbols" of Airy, by which Laplace *determines* the constant $A^{(2)}$.

On this point I quote from Mr. Airy's brief reply to Sir Wm. Thomson's criticism (changing however his symbols into those of Laplace):

"Now, an equation like this, which gives the third term in terms of the first and second, the fourth term in terms of the second and third, and so on, must have the first and second terms as

[4] "*Les résistances de tout genre que les eaux de la mer éprouvent dans leur mouvements*," for reason of which Laplace excludes such constants, are (to my mind) quite a different matter from an infinitesimal friction."—J. G. B.

foundations or origins wherefrom to start for the formation of the entire series. There is no more ground for inferring the second term from the general subordinate equation than for inferring the first term from it. The first and second terms must stand on their own foundation. The value of $A^{(1)}$ is perfectly clear, namely, $A^{(1)} = \frac{3}{4}\frac{L}{r^3 g} \cos^2 v$ (not deduced from the general subordinate equation). But how with regard to $A^{(2)}$? The subordinate equation $12(A^{(2)} - A^{(2)}) = 0$ gives no information whatever; and I infer from this that we may give to $A^{(2)}$ any value that we think fit (as regards the equation, unlimited by boundaries, etc., with which we started), or any value that may be required by physical circumstances not yet introduced (as the boundary of the sea). But does any arbitrary value of $A^{(2)}$ really satisfy the original equation? It does. Then I say that $A^{(2)}$ is truly an undetermined quantity, which may perhaps be determined hereafter by reference to physical conditions not yet stated, but which cannot under any circumstances be inferred from the general subordinate equation. And, so far as I know, the whole course of applied algebra does not offer a more certain conclusion. I scarcely need to add that I look upon Laplace's process as a mere sport with symbols, and upon Laplace's conclusions as a grievous error." (Phil. Mag. October, 1875.)

The *assumption* as we have seen, of a value $\frac{A^{(f+1)}}{A^{(f)}} =$ zero (or an indefinitely small quantity) determines all the ratios which precede it. Now let us see, *generally*, (*i. e.*, this assumption *not* made), how the final ratios are expressed. Expression (2) may be put in the form

$$(2)_2 \qquad A^{(f+2)} = \frac{2f+3}{2f+6} A^{(f+1)} - \frac{\frac{n^2}{lg}}{f(f+3)} A^{(f)}$$

If the ratio of $A^{(f+1)}$ to $A^{(f)}$ is not very small when f is very great, the final term becomes, *relatively* to the other two, a small quantity which may be omitted. Hence we get for the ultimate convergence of the coëfficients of the series for a, (1), when $\sin\theta = 1$;

$$\frac{A^{(f+2)}}{A^{(f+1)}} = \frac{2f+3}{2f+6} = 1 - \frac{3}{2f} \text{ (nearly)}$$

and for the consecutive coëfficients of those for $\frac{da}{d.\sin\theta}$ the ultimate ratio will be found to be

$$1 - \frac{1}{2f}$$

Degrees of convergence (slowly to unity) which, in general,

leave the convergency of series such as that (1) for a and $\frac{d\,a}{d,\ sin\ \theta}$ when $sin\ \theta$ is unity, doubtful. Subjected to the usual tests, the series (1) (for a, with $sin\ \theta = 1$) is convergent; that for $\frac{d\,a}{d,\ sin\ \theta}$ divergent or infinite; but to produce $\frac{d\,a}{d\,\theta}$ this last must be multiplied by $cos\ \theta$ which becomes zero. The resultant value is finite.[5] Or as Sir Wm. Thomson states, "when $sin\ \theta$ is nearly equal to unity, a *is finite;* and so *also* is $(1 - sin^2\theta)\frac{d\,a}{d,\ sin\ \theta}$, or $\frac{d\,a}{d\,\theta}$. Now, clearly, at the equator we must have $\frac{d\,a}{d\,\theta} = 0$ because of the symmetry of the disturbance in the northern and southern hemispheres." Hence, he argues, the ratio in question, instead of converging, as above, to $1 - \frac{3}{2\,f}$, or unity nearly, should *converge to zero*: *i.e.*, be that of Laplace's continued fraction: and hence that the series, (1), with coëfficients *thus* determined is *the only admissible one.*

When the coëfficients $A^{(2)}$, $A^{(4)}$ . . . . $A^{(f)}$, are (by form (2)) otherwise computed, from any *arbitrary* value of $A^{(2)}$, the series (1) will be made up of two sets of terms, one having $A^{(1)}$, the other $A^{(2)}$ as a common multiplier, thus

$$(4) \quad A^{(1)}\,(sin^2\,\theta + p^{(3)}\,sin^{(6)}\,\theta + p^{(4)}\,sin^{(8)}\,\theta \ldots + p^{(f)} sin^{2f}\,\theta \ldots)$$

$$(5) + A^{(2)}(sin^4\,\theta + q^{(3)}\,sin^6\,\theta + q^{(4)}\,sin^8\,\theta \ldots\ldots q^{(f)} sin^{2f}\,\theta \ldots)$$

The resultant value of any coëfficient of (1), $A^{(f)}$, being $A^{(1)}\,p^{(f)} + A^{(2)}\,q^{(f)}$, while $p^{(f)}, p^{(f+1)} \ldots q^{(f)}, q^{(f+1)}$ etc., are—each series independently—subject to the law governing the $A^{(f)}$ in (2); but as they do not result from the continued fraction, consecutive values must, for large values of f, converge, as shown by expression $(2)_2$, to near equality (involving uniformity of algebraic sign), in, respectively, *each* of the two series. That $\frac{A^{(f+1)}}{A^{(f)}}$ should be infinitely small implies that $\frac{p^{(f+1)} + \frac{A^{(2)}}{A^{(1)}}\,q^{(f+1)}}{p^{(f)} \quad + \frac{A^{(2)}}{A^{(1)}}\,q^{(f)}}$

[5] It is Sir Wm. Thomson's remark that the rate of convergency, $1 - \frac{3}{2\,f}$, is exactly that of development of $(1 - x^2)^{\frac{1}{2}}$ when x is unity; or, in other words, of the *cosine* developed in terms of the *sine*. For the same reason that $\frac{d\,(1-x^2)^{\frac{1}{2}}}{dx}$ (or, $\frac{x}{(1-x^2)^{\frac{1}{2}}}$) is infinite, while $(1-x^2)^{\frac{1}{2}}\,\frac{d\,(1-x^2)^{\frac{1}{2}}}{dx}$ is finite (with $x = 1$); so are $\frac{d\,a}{d\ sin\ \theta}$ infinite, and $\frac{d\,a}{d\,\theta}$ *finite* when (with above convergencies) $sin\ \theta = 1$.

should be infinitely small when $\frac{A^{(2)}}{A^{(1)}}$ is determined by the continued fraction. But if the p's and q's were *both* positive this ratio would be unity (nearly). The first set (4) (for given sea depth) is always the same; the other (5), for all values of $A^{(2)}$ and same sea depth must be of reverse (ultimate) sign, and the *difference* of the two terms of the numerator must, for this (Laplace's) particular value of $\frac{A^{(2)}}{A^{(1)}}$, be infinitesimal *compared* to that of the two terms of the denominator; and it is clear that $\frac{A^{(2)}}{A^{(1)}}$ can differ but *slightly* from $-\frac{pf}{qf}$, or from the *ultimate ratio* of the p's and the q's.

According to Sir Wm. Thomson, "Laplace's process simply determines $A^{(2)}$ to fulfil the condition that $\frac{da}{d\theta} = 0$ at the equator. . . . . Laplace's result is therefore the solution of the determinate problem of finding the tidal motion in an ocean covering the whole earth continuously from pole to pole."

If the series (1) fails at the equator by yielding a finite and therefore impossible value for $\frac{da}{d\theta}$ (the symmetry of the tidal form for the two hemispheres renders such a value impossible), must it, therefore, be rejected everywhere else, even though except in a very narrow equatorial zone, the series is rapidly convergent yielding values of tidal rise and motion consistent with the conditions of the problem?

The question involved is whether, in a frictionless perfectly fluid ocean of *uniform depth*, simple semi-diurnal tidal waves are possible results of the semi-diurnal terms of the solar and lunar attractions unaided by the free wave expressed by Laplace's value of the arbitrary constant $A^{(2)}$. I incline to the belief that such wave-forms (or at any rate such as extend from pole to pole) are limited to the case in which the depth (as it ought) diminishes, as the $sin^2\,\theta$ (*i. e.* as the square of the necessary longitudinal velocity of *wave motion*) and in which the tidal rise varies with latitude as does the semi-diurnal term of the potential of the disturbing force (likewise as the $sin^2\,\theta$). This case alone yields (Airy, § 108) a solution in a *finite* form, and moreover, without the aid of an (independent of the sustaining force) auxiliary wave.

None of the commentators have contested that the expression (5) represents an arbitrary oscillation independent of, and unsustained by, the tide-producing force. Hence it is one which "must

(in the language of Laplace) quickly have disappeared by resistances of various kinds." It is indeed quite true that his analysis has disregarded all these "resistances," and that its "particular integrals" which are offered us as "solutions" could only be realized as phenomena, by "perfect" and "frictionless" fluids — that the very motions these integrals imply must be *initially* given — that the tide-producing influence does not *generate* (and *therefore* cannot be truly said to *cause*) them; when they are once *initially* imparted it so modifies, over the surface of the earth, the force of gravity, that these waves will *maintain themselves*, if there be no "resistances."

Nevertheless, although "oscillations" (of this determinate *initial* kind) "which depend on *a* primitive state of the sea," *must therefore* be implied, we are, after all, seeking to *approximate* our theoretical to *actual tides*[6] (or at least to what actual tides would be, did the ocean extent and bottom correspond to assumption) and therefore Laplace, not merely to make integration practicable but in the cause of truth itself, "rules out" *all* "primitive oscillations" which do *not* "depend on the action" of "the sun and moon." Nothing can be more explicit in language, nor more clear in its reason, however unsatisfactory the result may yet be thought, still failing as it does to express the actual tides of nature.

Laplace's ruling and its rationale alike forbid the introduction of arbitrary constants into these particular integrals which "satisfy" his general differential equation [2380] (Bowditch). They (the constants) represent oscillations (even though —a subordinate case — they are used to limit the ocean surface) which do *not* "depend on the action of these bodies" (the sun and moon); do not

[6] If this be not the object, we might quite properly begin with what would be esteemed the most natural beginning, *i. e.*, a state of rest. We should then (supposing the problem solved) have a tidal development, waxing from zero over the whole surface to its maximum phase in some unknown "period,"— varied by the diurnal or semi-diurnal effects of the tide generating force — and waning back again; complicated phenomena having several "periods" and corresponding to nothing *actual* (See Airy, § 294, for a *canal*).

If "resistances" be considered, it is quite true (though in no other case) that "oscillations depending on the primitive state of the sea, "need not be taken account of. *This* is what I suppose Sir Wm. Thomson to mean in his paragraph 11, though I see no ground for taking exception (as he does) to the prefatory ruling of Laplace, who does *not* take account of them. My own comment was:—

"Such is the problem of Laplace; but the *real* problem is this: Since all initial disturbances speedily vanish, therefore a state of equilibrium may be assumed as the 'primitive state of the sea;'—and the problem becomes, "from a state of equilibrium to find what at any future time would be, subjected to the action of the foreign attraction *and* of resistances of different kinds, the form and motions of the sea."

vanish with it; and hence must be self-sustenant, which they can *not* be since they "would quickly have disappeared by resistances of different kinds."[7]

The matter involved in the question of this alleged error is of the slightest practical importance. The results of Laplace's celebrated theory, owing, as stated by himself, to "the irregularity of the depth of the ocean, the manner in which it is spread over the earth, the position and declivity of the shores, their connections with the adjoining coasts, the currents, and the resistances which the waters suffer," have little relation to the actual tides; and indeed (if we except the long period tides, identical in expression by the "equilibrium" and the Laplace theories), scarcely any more real relation even when the hypothetical ocean and absence of resistances (of the analysis) are conceded. Forced to disregard the proper motions of the sun and moon they are, even then, mere mechanical theorems. The profound generalization with which the problem at the outset is set forth, and the transcendental character of the analysis applied, only make more conspicuous the paucity and *particularity* of its results; all of which can be attained by very simple considerations;[8] and none of which have been (in contrast to the decried equilibrium theory), of any practical value in tidal discussions, not even in those subsequently made by Laplace himself. Far more just to my mind than the exalted eulogy of Mr. Airy, *Tides and Waves*, § 117, quoted, with concurrence, as the concluding paragraph of Sir Wm. Thomson's paper, is the comment of Prof. Forbes (6th Dissertation Encyc. Britta., 8th Ed.) :—

"It is, in fact, like many other productions of the same age and school, a great display of ingenuity and mathematical skill, which hardly yields a single result worthy of confidence or agreeing

[7] As to the objections that any of these (expression 5) A^2-valued free waves of semi-diurnal period can only exist with certain "critical depths" —that with such depths (as in *canals*), the corresponding "forced" (or true tide) wave *would be infinite;* I can only reply that I know no such "critical depth" for *uniform* sea-depths, since the wave velocities must vary with the cosine of the latitudes, demanding *by this rule*, for each latitude a different depth: that for *all* values of $A^{(2)}$, they, whether or not combined with the forced wave, fulfil for all depths the equation which expresses the dynamic conditions of the problem. Incidentally I remark that the internal motion involved is quite different from that of the free *canal*-wave (which seems to be made a criterion); and that for Laplace's first example (depth $=\frac{1}{2\times 90}$, or $1\frac{1}{3}$ mile) when the tide is inverted (*negative*) near the equator and direct (*positive*) above 18° (the latitude at which the free canal-wave moves synchronously with the force), the transition resulting from the analytical expression is *not* through infinity but through zero.

[8] See (*e. g.*) Mr. D. D. Heath's paper, in the "Philosophical Magazine," May, 1867.

with nature, except by the abandonment of its deductive rigor, or a concealed induction backward from the phenomena to be accounted for."

Mr. Airy himself, almost in the same breath of his eulogy, says: "As it is, Laplace's theory fails totally in application, from the impossibility of introducing in it the consideration of the boundaries of the sea. . . . . If we look to the results of the theory, it will be found that they are rather of a negative than of a positive kind." He then specifies these "negative" results as follows: "*they show*" he says, "*that without a far more complete knowledge of the form of the bottom of the sea than we can hope to possess, it will be impossible, even with more powerful mathematics, to calculate tides à priori . . . . that calculations founded on the equilibrium theory cannot be good for anything.*"

"*In proving that* (*with the sea at least of a certain shallowness*) *the part of the equator next the moon would be the place of low water, they destroy all hope of using the equilibrium theory, even as an approximation. In establishing the remarkable result as to the non-existence of diurnal tide in height when the depth is uniform, they show that no inference can be drawn from the mere magnitude of a force as to the magnitude of the effects.*" (Airy, "Tides and Waves," § 118.)

"It does not seem to me (I stated many years ago, Am. Jour. of Science, 1859), that so difficult and profound a course of analysis was at all necessary to arrive at these negative results." Even the *inverted* tides—and the *nil* diurnal tide (the *most* remarkable results)—have been otherwise easily inferred (see Mr. Heath's paper above alluded to): while few will concur in the astonishingly broad and even paradoxical statement based on the latter, "that no inference can be drawn from the magnitude of a force *to the magnitude of its effects.*" [9]

[9] I remark elsewhere, that the motions indicated by the particular integrals of Laplace's solutions are, in no proper sense, *effects* of the foreign attractions—not being *generated* by them but needing *initial* establishment; that particular tidal phenomenon upon which Mr. Airy bases the above startling conclusion furnishing an apt illustration. Not only is there "non existence of diurnal tide in *height*," but there is, *absolutely* speaking, "non existence" of other *motion* than that of *pre-existent* diurnal rotation; the *relative* motion of the water, as regards the nucleus, being due to a slightly shifted position of the diurnal rotation axis of the aqueous shell, as if it were solid, a shifting not *produced* by the sun or moon; to maintain the ever varying degree and direction of which in harmony with the motions of these bodies, a "*deus ex machina*" must be invoked.

Of the three tidal forms as *worked out* by Laplace (though doubtless his analysis opens the way to much greater refinement of solution), that for the secular (semi-annual or semi-monthly) tide is identically that of the "equilibrium theory." That for the diurnal, with its revelation of *nil* tidal elevation for uniform ocean depth, expresses a "purely mechanical theorem, alien to the conditions under which 'tides' are generated" (see paper cited in "Proceedings A. A. A. S.," 1876). That for the semi-diurnal tides, of doubtful applicability, has just been commented upon. The only *finite* solution for this case (see page 79), due to Mr. Airy, and not to Laplace, applies not to uniform depth, but to depths vanishing at the poles.

It is somewhat amusing that Laplace gravely prefaces his final resort for semi-diurnal tides, the assumption of uniform depths (and announces its motive) thus: "We have remarked that to satisfy the observations we must suppose the depth of the sea to be nearly constant."

The "observations" denoted are that in our seas the two semi-diurnals of the same day differ little in height—and hence, since there are, apparently, no *diurnal* tides, his nil-diurnal tidal theorem implies "constancy" of sea depth. Whereas in the Pacific, the largest ocean area, the diurnals are really conspicuous, vying in magnitude with the semi-diurnals. The investigation, doubtless, has a more adequate motive than that derived from a comparison of the results of a so purely mechanical and non-applicable theorem with the actual phenomena of tides in our oceans, where none of the hypothetical geodesic conditions are fulfilled, and where the disregard of the proper motions of the sun and moon makes the theorem itself "alien" to tidal conditions. A like disregard (a retreat from the difficulties of the problem) of the proper motions of the attracting bodies—of the density of the water—makes this semi-diurnal tidal expression, otherwise unsatisfactory as we have found it to be, little more than *another* mere mechanical and non-applicable theorem; and having no claim of superiority as a representation of *facts* over the equilibrium theory.

Indeed the so-called "dynamic" theory of Laplace, judged by its ultimate expressions, is essentially *an* "equilibrium" theory involving motion indeed, but *a* motion of invariable modulus while dependent on ephemeral conditions; exacting that the sun and moon "stand still;" a motion *not* called into existence by the

tide-causing force which in nature is incessantly generating and *re*-generating tidal motions *pari-passu* as they are destroyed by "resistances," rendered abnormal by winds or earthquakes, or varied to correspond to its own fluctuating nature. In portraying the tides of nature as an *initially impressed* disturbance (no more capable of maintaining its *integrity* than is the "free-wave" *its existence* against the "resistances") its indications of the magnitude of development and of the disposition of the tidal elevations are quite as fallacious as, and more unlike nature than, those of the equilibrium theory, even if we concede the non-natural continuous ocean and simple law of depth to which as the only solution-yielding hypothesis, the theory is driven.

It is not contended that the "dynamic" theory with its initial "wave" (the *wave* being a form in which a true dynamic theory must necessarily reveal itself) is not an advance on the rude equilibrium theory. It *is* contended that the unlimited breadth of generalization with which the investigation is commenced, and the formidable analytical machinery brought to bear, result through ultimate abandonment of all that is general, and nearly all that is *natural*, only in mechanical theorems which, however elegant, are alien to the tides of nature, or, if we seek in them results *not* "alien," they turn out to be a few "negative" propositions of the most *special* character, all, moreover, otherwise easily obtained.

Laplace's great English contemporary, Young, is the true founder of a "dynamic theory" of the tides (Encyc. Britta., Supplement to 6th Ed., reprinted in the 7th and 8th). He takes, indeed, wave motion as his basis, but couples it inseparably with the resistances which nature has inseparably combined with all motion on the earth's surface; and which, in the case of the tides, is so powerfully a controlling agent, that without them tidal expressions, if not "mere sport with symbols," are but mechanical theorems of impossible realization, however beautiful *as such* and however captivating or profitable, in a mathematical sense, may be the research.

On a New Type of Steam Engine, theoretically capable of utilizing the full Mechanical Equivalent of Heat-energy, and on some points in Theory indicating its practicability.

By Robert H. Thurston, of Hoboken, N. J.

[ABSTRACT.[1]]

I. It is easy to show that the existing Common Type of Steam Engine necessarily wastes a very large proportion of the Heat-energy supplied to it, and that no possible improvement short of a complete change of type can greatly increase the efficiency of the best modern engine. No engine theoretically capable of utilizing all heat-energy supplied to it by the steam has yet been constructed and the possibility of its construction has been denied, both by engineers and by physicists.

This paper was intended to show the possibility of designing, and the probable practicability of constructing, a steam engine that shall waste heat only by conduction and radiation, and which shall waste energy only by friction. The new type is only adapted to use working fluids which are not permanent gases, but which behave like steam.

II. Sadi Carnot showed, a half century ago, the proper method of test of a perfect heat engine, and that the operation of the engine must be traced through a complete cycle. Such a cycle is a *closed curve of conditions.* The heat-cycle usually corresponds with a kinematic cycle of the engine. In each cycle a certain amount of heat-energy is supplied to the machine, and a certain other amount of mechanical work is done by the machine upon external objects and on its own moving parts. Call these quantities A and A′. Imagine the engine reversed. If perfect, every operation is, during this inverted cycle, given a negative direction and the net result is the reconversion of the heat A′ from the mechanical energy, A, expended in driving the engine backward. Such an engine must be perfect, since, if not, if coupled to an engine more nearly perfect and driven backward by the latter, the former would restore heat to the source from which the latter may receive it. The amount restored is the full mechanical equivalent of the work expended. But the more perfect engine demands

[1] For the complete paper, see Journal of the Franklin Institute, Oct., Nov., Dec., 1877.

less heat than the less perfect machine. Hence there must be an accumulation of heat in the reservoir—a "*reductio ad absurdum*."

The principle of the "Conservation of Energy" asserts that no energy in a system can be extinguished. Hence in any heat-engine, energy not expended in production of the mechanical work or of friction, or dispersed by conduction or radiation, must reappear in its original form of heat motion. A perfect heat-engine, as here defined, is one in which no heat is lost by conduction, or radiation, or by friction, and in which all heat not discharged unutilized, at the completion of the cycle, is usefully applied by conversion into mechanical energy.

Carnot's somewhat faulty conception was perfected by Sir William Thomson, in 1849, and it now enables us to determine the efficiency of a perfect engine working under any given set of conditions as to temperature.

III. In illustration, a diagram such as James Watt (1800) obtained from steam-engines, and such as Clapeyron (1834) used to exhibit theoretical conditions, is presented to show the changes of the volume and pressure of steam during a cycle, including expansion, doing work adiabatically and isothermally, and compression adiabatically and isothermally. The result is the conversion of a certain amount of heat into work, and the restoration of the fluid to its initial condition as to pressure, volume and temperature.

IV. Carnot showed the maximum of the perfect gas engine to be

$$E = \frac{\tau - \tau^1}{\tau},$$

where τ and τ^1 are the temperatures of admission and rejection of heat measured from the zero of heat motion. Benjamin Thompson, Count Rumford, in 1798, showed the true nature of heat, and gave data from which an approximate value of the mechanical equivalent can be calculated. Joule, 1843–1849, determined this quantity with probable great accuracy. Sir William Thomson, 1849, gave the absolute scale of temperature ($0 = -461.2$ F. $= -273.55$ C.) as an absolute measure of quantities of heat. The British Thermal Unit is equal to 772 foot-pounds of energy; the French *Calorie* is equivalent to 424 kilogrammetres of work.

V. When, as is the case with steam, a working fluid experiences a change of physical state in the engine, Carnot and Thomson's measure of efficiency is not correct. For absolute correctness the specific heat must remain constant.

VI. Heat-engines are divided for present purposes into three classes: —

1. Those which restore to the reservoir all heat rejected from the working cylinder.

2. Those which restore part and reject the remaining heat from the system.

3. Those which waste all heat rejected from the working cylinder.

No existing type of steam-engine is of the first class. Some air and gas engines are theoretically assignable to that class, as, by means of regenerators, they store up and save heat rejected from the working cylinder. Actually, however, such engines being imperfect structurally, they are of the second class. Most engines, including the steam-engine, are of the third class.

VII. The steam-engine differs radically in one, and hitherto rarely noted, point from all air and gas engines. In the latter,

$$\frac{\tau - \tau^1}{\tau} = \frac{Q - Q^1}{Q}$$

where the temperatures on the absolute scale, τ, τ^1, are proportional to the quantities of heat Q, Q^1, at the beginning and the end of the expansion. This is approximately true of dry and superheated steam. It is not at all true, however, of a mixture of vapor and liquid such as is seen in a working steam-engine.

This distinction is rendered more marked by the occurrence of considerable internal condensation at the beginning of, and re-evaporation during, the stroke of the engine. Even if this does not occur, the steam being worked in a perfectly non-conducting steam-cylinder, condensation of steam always occurs when the saturated vapor expands doing work, and we have, instead of $\tau : \tau^1 = Q : Q^1$,

$$\frac{Q - Q^1}{Q} > \frac{\tau - \tau^1}{\tau}.$$

Hence the steam-engine *should* be more economical than the air or other permanent gas engine working between the same limit of temperature. Hence also, the usually accepted method of estimating efficiency is not correct as applied to the steam-engine.

VIII. Neglecting the inaccuracy here pointed out and assuming

$$\frac{Q - Q^1}{Q} = \frac{\tau - \tau^1}{\tau},$$

the efficiency of a marine engine of the most successful type,

working steam of ninety pounds pressure and 320° F. (160°C.) temperature down to a condenser-pressure of two pounds and a temperature of 126° F. (53° C.), should be:

$$\frac{320-126}{781.2} = \frac{160-53}{431} = 0.25 +$$

and it should do $772 \times 0.25 = 193$ foot-pounds of work for each British thermal unit of heat supplied to it. This would be about 10,000 heat-units per hour per horse-power, which is the thermal content of ten pounds of steam, and about equivalent to the consumption of one pound of coal. Perfect utilization would give the horse-power for one-fourth this quantity, — for $2\frac{1}{2}$ pounds of steam, or $\frac{1}{4}$ pound of coal.

But, as just shown, the real theoretical efficiency must be still higher than this.

Good engines to-day waste nine-tenths the heat developed in the boiler, requiring, usually, twenty pounds of steam, or two pounds of coal per hour and per horse-power.

IX. The sources of loss in the engine are:

1. Friction.

2. Conduction and radiation of heat.

3. The rejection of unutilized heat in the exhaust steam.

The first two can be reduced to an unimportant fraction of the whole heat supplied. The last is to be studied in order to determine upon some method of considerably increasing the efficiency of the engine.

X. Rejected heat consists of two parts:

1. That which constitutes the principal part of the heat supplied and which, as already shown, is necessarily lost in the common type of engine.

2. That which, by the operation of condensation on entrance and subsequent reëvaporation, is transferred to the exhaust without doing its share of work.

The first method of loss has been explained: the second is not well understood, frequently, even by professional engineers. When steam enters the cylinder, it meets a comparatively cool metallic surface and a portion is condensed, the metal, meantime, acquiring the temperature of the steam. During the expansion, the consequent reduction of pressure produces a reëvaporation of this water of condensation, and the cylinder surface supplying the latent heat

of vaporization, becomes again cooled. On the opening of the exhaust-valve, a still further loss of heat occurs, all of which is carried with the exhaust-steam into the condenser, leaving the metal chilled, and it only becomes heated again when the next charge of steam enters the cylinder from the steam-chest.

This is a most serious cause of waste of heat. It sometimes even exceeds that unavoidable waste which occurs at the lower limit of temperature at which heat is rejected. This action places a limit to the economy derived by expansion, since this loss increases at a certain point more rapidly than efficiency is gained by increased expansion. Steam of sixty or seventy pounds pressure cannot ordinarily be expanded more than five or six times.

Thus the lost heat of the common form of engine consists of two parts, of which a proportion, $\frac{Q^1}{Q} \times U$, of the total heat supplied can only be saved by some radical change of type. The second part has been diminished in amount, but never wholly checked, by known expedients, and may require equally radical treatment.

Such a change might, possibly, if completely effective, reduce the cost of power, assuming an efficiency of one-half, to five pounds of steam, or one-half pound of coal per hour and per horse-power,[2] the working pressure remaining as at present in our best engines.

XI. There are two types of engine of Class 1, in which, could we build them, this waste could be avoided:

Type A. The working fluid, if expanded quite down to the absolute zero, would transform all heat-energy into work, and the efficiency would be perfect.

Type B. All heat rejected from the cylinder unutilized, being gathered up and restored to the boiler, there to serve as a basis on which to pile a new stock of transformable heat-energy, no heat would be lost, and the efficiency of the machine would be perfect.

Forms of engines of these types may be conceived; but, practically, the first type can never be constructed, since the volume and weight of the machine would be immensely great.

The same objection, in a less degree, would hold against the second type.

[2] Good engines of the common type should work on $W = \frac{200}{\sqrt{P}}$; the best practice gives about $W = \frac{150}{\sqrt{P}}$, where W is the weight of steam and P the steam pressure.

It follows that we are to look for improvement in the latter direction, returning to the reservoir all heat rejected from the steam cylinder of the common engine.

XII. Experiment has not yet fully determined the distribution of heat throughout the scale of temperature in either water or steam, or the method of change of physical state where temperature approaches either the absolute zero, or those pressures with which Dr. Andrews and other physicists, and Perkins, Alban and others among engineers, were familiar. It cannot be said, therefore, what would be the behavior of the fluid in an engine of the first type, and we cannot even imagine how far the theory of heat-engines, as usually accepted, may apply when the range of temperature of the working fluid shall have been greatly extended. It seems probable, however, that the steam-engine may have a theoretical efficiency greater than has been previously supposed.

XIII. An engine of Class A can only exist when expansion is complete, leaving the working substance at the absolute zero of temperature and deprived of all heat-energy.

But Sir William Thomson has enunciated the principle:

"It is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter, by cooling it below the temperature of the coldest of the surrounding objects."[3]

This principle is not correct, as stated, except as it implies the existence of certain conditions which are practically persistent, including the use of a permanent gas as the working fluid, or of a substance which does not change its physical state in such a manner, during the conversion of heat into mechanical work, as to invalidate the asserted law. Heat-motion *is not* limited theoretically in its conversion into mechanical energy, and *may not be* limited practically, by the temperature of the earth's surface.

XIV. To show that heat may be converted into work to any extent, regardless of the temperature of surrounding bodies, we may trace the process in two cases:

1. Where the working fluid is a permanent gas.

2. Where it is a fluid subject to change of physical state, as, for example, steam.

In the first case, the fluid expands, doing work, until all heat-energy is converted into mechanical work and the substance is finally left diffused through a vast space, its molecules absolutely

[3] On the Dynamical Theory of heat, etc., R. S. E., 1851.

at rest and without vibratory motion.[4] Had no work been done, this space would be of infinite extent, but the conversion of heat-energy into mechanical energy tends to restrict this dispersion.

The removal of a particle from one point in space to another requires no expenditure of energy, that absorbed in giving it its maximum velocity in transit being restored by it while again coming to rest. Thus it may be possible to gather up all the scattered particles and, collecting them about this common centre of gravity, where they will occupy the volume of the gas in the solid state and at absolute zero in temperature, this mass may now be transferred to the reservoir by the expenditure of an indefinitely small amount of energy. Repeating this process indefinitely, the engine is perfect in every sense, and has an efficiency of unity.

It is evident that the engine is unaffected by the temperature of bodies surrounding it. Were the upper limit of temperature that of the earth's surface, and the working substance air, the reservoir being the atmosphere, the indefinite continuance of this operation would result in the conversion of all heat-energy into mechanical energy, and the cooling of the earth down to the absolute zero of temperature. Applying this energy to the acceleration of the earth's motion in its orbit, it would result in an increase of about one mile per second, the mean temperature being assumed at 1500° C., and the specific heat at 0.2.

XV. Repeating the operation, using a working fluid which, like steam, changes its physical state, condensing into liquid, while doing work by its expansion, an accumulation of liquid occurs in the steam cylinder during the expansion, which, if the operation is continued to the limit as before, becomes, finally, a solid mass of ice at absolute zero. The remaining, and a very minute, proportion of the charge is also at the absolute zero of temperature, but with its particles widely separated as in the preceding case.

The great mass of the working substance which has become solid, and the minute portion of diffused matter are now to be restored to the reservoir, completing the cycle.

In producing the solid mass which contains nearly all the work-

[4] This may be too unqualified a statement. An indefinite amount of energy of rotation may, perhaps, be retained after all energy of motion of translation has been removed by expansion. It is not certain, therefore, that all heat-energy may be removed by expansion.

ing substance, nature has here done what, in the first example, must have been done artificially. This engine, also, is evidently perfect and has an efficiency of unity.

XVI. Many and serious practical difficulties will impede attempts to realize, even approximately, the conditions here described, but we may approximate more and more closely, without limit, as we advance in scientific knowledge and constructive skill.

XVII. Thomson appends to his proposition (which has been called an axiom) the following note:

"But if this be denied for all temperatures, it would have to be admitted that a self-acting machine might be set to work and produce mechanical effect by cooling the sea or earth, with no limit but the total loss of heat from the earth and sea, or, in reality, from the whole material world."

Yet we have seen that such an engine might, by some intelligence, mighty, but not necessarily infinite, be set at work to produce mechanical effect by cooling sea, earth and air.

The machine may go on and *abstract all the heat from the universe*. Thomson's qualification of his "axiom" does not, evidently, confirm the principle which he has enunciated. Our self-acting machine *might* cool down "the whole material world."

XVIII. The practical difficulties which stand in the way of the engineer who attempts to effect the realization of these ideal perfect engines may be anticipated, and, to a certain extent, it may be determined how we may best proceed to attack them.

Type A is seen, at once, to be utterly impracticable. With a permanent gas as the working fluid, space could not be found for the expansion of the gas nearly to the absolute zero; the resistances due to friction would be greater than the mean pressure exerted on the piston; and we know, *as yet*, no means of collecting the scattered particles without producing collisions among them, which would generate heat and compel the expenditure of energy in the restoration of the condensed gas to the reservoir. In all known methods of compression, the heat developed is equal to that transformed in the expansion. The practical limit here is that assigned by Thomson to the ideal engine.

The use of condensable fluids is attended by similar difficulties. Such fluids, however, demanding less space into which to expand, offer, to that extent, an advantage.

Assuming the possibility of making a steam-engine of Type A, working steam of seventy-five pounds pressure by gauge, from a temperature of 320° F. (160° C.), the work done during expansion per pound of steam would be 910.557 foot-pounds; the work of restoration of the ice made would be 38½ pounds; and the efficiency would be (910.557 — 38.5) ÷ 910,557 = 0.9999 = E.

Complete utilization of heat is impracticable in any conceivable form of engine of Type A.[5]

XIX. Type B, in which all unutilized heat is restored to the reservoir, comprehends two quite different forms of engine:

1. Heat-engines in which the rejected heat is transferred from the mass of working substance discharged from the working cylinder to a mass of metal, or other heat-absorbing substance, and from the latter to another, and new, charge of the working fluid which is about entering the reservoir to take up a new stock of heat-energy.

2. Heat-engines in which, as in the ideal engines described, the rejected working fluid itself, with its contained unutilized heat, is all returned to the reservoir.

XX. Engines of the first of these two classes have been frequently designed and constructed. That part which receives and restores the heat by transfer, has been known as a "Regenerator." It never acts with thorough efficiency, and the loss of energy is always considerable. Nevertheless, air-engines fitted with regenerators have proved comparatively economical. Ericsson's engines, in the steamer of that name, were reported by Prof. Norton to have developed their full power (350 I. H. P.) with an expenditure of 1.87 pounds of coal per hour per horse power.

The regenerator is, however, entirely inapplicable to engines in which steam and other saturated vapors are employed.

It is, however, possible, in such engines, to save a portion of heat by transfer, using, as the absorber of that heat, a liquid having a boiling point lower than that of the liquid formed by the condensation of the working fluid of the first engine, the vapor of which absorbent-liquid is used as a working substance for a second

[5] The two kinds of fluid are here seen to exhibit the two characteristic products of the two methods of abstraction of heat from gases: 1. Forcibly compress the fluid, removing the heat produced, as fast as it is generated; the product is a solid of maximum density, and at the absolute zero. 2. Abstract the heat by expansion against a resistance; the product is a diffused mass, without tension, of minimum density and without heat-motion.

heat-engine. Such a combination has been made, and is known among engineers as the "Binary Vapor Engine;" its working fluids have been steam, and either the vapor of ether, or chloroform, or of bisulphide of carbon. Could the required fluids be found, such a series could be continued indefinitely, or until the mean pressure of the expanding vapor should become less than frictional resistances.

XXI. It would be better to conduct this operation of re-working rejected heat by passing it through the first cylinder again, than by the use of Binary Vapor Engines.

The Regenerator system is here inapplicable (using vapors), and it is evidently a more promising plan to endeavor to return the gas and the liquid resulting from condensation to the reservoir with their full charge of rejected heat, a process, the success of which, is favored by the very conditions which preclude the use of the regenerator. We are thus led to the use of Type B.

Suppose this action carried out. Imagine the rejected steam and water returned separately to the reservoir by compressing pumps. The return of the water would require the expenditure of an amount of work measured by the product of its volume into the pressure in the reservoir. Returning the uncondensed steam, rejected from the working cylinder, would involve not only the return of the heat in that steam, but also of an additional amount of energy equivalent to that which the vapor so returned had yielded during expansion.

Thus all heat rejected unutilized would be returned to the boiler, there to form "a basis on which to pile up a new stock of utilizable energy," and perfect theoretical efficiency is secured for all ranges of temperature and for all such working fluids.

The work of restoration of the liquid is so small that it may be neglected. That done in a steam-engine of the common type having an efficiency of 0.25, in compressing the vapor, after alteration into the new type, would be nearly in the ratio $(1 - 0.25) : 1 = 0.75$, as compared with the work of expansion. The more the steam is expanded, the greater the proportion condensed, and the less the amount left to be returned, as steam, to the boiler.

It is also seen that, to obtain greatest success in the effort to secure high efficiency and small volume, high steam must be used with great expansion; and to reduce internal condensation and reëvaporation, a high velocity of piston and speed of rotation.

XXII. The term "Efficiency" is rarely accurately defined or well understood. By *efficiency of the fluid* should be understood the ratio of the quantity of work done by the working substance to the mechanical equivalent of its thermal contents at the instant of entering the cylinder of the engine, which ratio is measured by the quantity $\frac{Q-Q^1}{Q} = E$.

The *efficiency of the engine* is the ratio of the work done by the engine in a given period to the mechanical equivalent of the heat supplied to the engine. The *efficiency of the boiler* is the ratio of heat delivered by it in dry steam to the amount of heat developed in its furnace by the combustion of fuel.

The efficiency of the engine is also often taken as the efficiency of the whole combination of engine and its fluid with the boiler and its furnace. These quantities are often confounded. It is often incorrectly assumed that the efficiency of the steam-engine is limited precisely by that of its working fluid as measured by Thompson and Carnot, an assumption seen to be false when it is remembered that the estimate takes no cognizance of the temperature of the fluid when supplied to the boiler, or of the final disposition of rejected heat.

Assume that two engines are using steam of ninety pounds, absolute pressure, working down to a condenser-pressure of two pounds, *i. e.*, working between temperature-limits of 320° F., or 180° C., and 126°.27 F. or 52°.37 C., one engine being of the ordinary type and the other of the new type. Let the steam expand in both from the upper to the lower limit.

In determining the value of $E = \frac{Q-Q^1}{Q}$ for the common engine, Q being the amount of heat supplied to each pound of steam by the fuel in the boiler, and Q^1 as the quantity rejected from the cylinder and discharged from the engine, and assuming no loss by conduction, radiation or friction, we first get: quantity of heat supplied to the steam, $1{,}211.5 - 110 = 1{,}101.5$ units per pound; quantity of heat rejected from the engine in steam, $1.152.5 - 110 = 1.042.5$ units per pound; quantity in water, $126.27 - 110 = 16.27$ units.

The total weights are readily calculated.

Taking Rankine's expression for the expansion of steam, $PV^x = C$, and introducing the value of x determined, according to McCulloch, by Zeuner,— four thirds,— we find, where, as with

steam of ninety pounds pressure, the original volume is $V = 4.72$ cubic feet, we get the value of $C = 102.611$, using $P = 90 \times 144$.

From our equation, we then get, for $P = 2 \times 144$, $V = 76.53$.

But the volume of one pound of steam at this pressure is 172.4 cubic feet. Then it follows that of steam rejected uncondensed, per pound, we have $76.534 \div 172.4 = 0.444$ lb. Of water, there is rejected, per pound, 0.556 lb. This carries with it $1042.5 \times 0.444 = 462.85$ units, and the water $16.27 \times 0.556 = 9.05$ units, making a total of 471.9 units of heat lost. The efficiency of the ordinary type of engine, working under such conditions, therefore, has a theoretical maximum of 0.57, or nearly sixty per cent. instead of twenty-five.

This corresponds to a consumption of $1{,}980{,}000 \div (1{,}101.5 \times 772) \div 0.57$, = four pounds of *steam* per hour and per horse-power, and to about $\frac{2}{3}$ pound of coal.

In actual engines five times as much is used.

The difference between the actual and the ideal efficiency of steam-engines has usually been supposed much less, and the range for further improvement much less than is now inferable. It has been thought that the best steam-engines were within fifteen per cent. of the limit of perfect efficiency, while it is here seen to lack more nearly forty per cent.

The direction of improvement is plainly to be in that of the reduction of the losses due to internal condensation and reëvaporation, by, if possible, the use of a non-conducting lining as practised by Smeaton and Watt,— who used wood a century ago, but unsuccessfully in consequence of its perishability,— and by increasing piston-speed and velocity of rotation. With low speed of piston, superheating can be resorted to.

Increasing steam pressures and expansion is productive of but very slight proportional gain in efficiency. Steam at 250 pounds pressure affords but about five per cent. increase of efficiency over that derived by the use of steam at seventy-five pounds.

XXIII. The question whether an engine of Type B can be made practically successful is only determinable by careful and intelligent experimental investigation.

Safety may be always secured, in its use, by intelligent design, good material and workmanship, and skilful management. Danger need not necessarily be expected from high pressures, since

Perkins and Albans successfully controlled and worked steam at pressures of 1000 and 2000 pounds, forty years ago.

Efficiency will be determined largely by the size of the engine. Replacing an engine of the old type, working with E = 0.20, by one of the new form, it will be necessary to make the latter of five times the piston displacement of the old engine, or to drive the new engine at five times the speed of the older engine. Making all allowances, the probable consumption of heat in the new engine, if replacing a modern marine steam-engine, may be taken as not far from 8000 British thermal units per hour per horse power, or from $\frac{3}{4}$ to $\frac{4}{5}$ pound of good coal, — about $\frac{1}{3}$ or $\frac{1}{4}$ that required for the best existing type of marine engine in extended use.

The new engine should demand but 250 tons of coal for a voyage across the Atlantic where 1000 tons are now used, and would occupy little, if any, more space in the ship. It would weigh more, but this would be more than compensated by the great decrease in number of boilers needed, and of coal-bunker compacity.

XXIV. Several forms of engine have been devised, since 1858–9, by the author of this paper, all of which are of Type B, and any expert mechanical engineer may devise methods of conversion of the common engine into this type.

No one can say when the actual introduction of such an engine may be expected. The time will be shortened by every change facilitating the use of higher steam-pressures, greater piston-speeds, care and skill in design, the use of better materials, greater perfection of workmanship, and intelligence in management.

We are continually learning that steam is a better medium for the conversion of heat into mechanical power than we had previously supposed. We have above seen that it is capable of far more perfect utilization than we had been taught by accepted authorities to consider possible. It is possible that even these corrected estimates of efficiency give an inadequate idea of the true efficiency of the fluid in the perfect steam-engine. We know comparatively little of the physical properties of steam at the temperatures and pressures known to be attainable, and it may prove to be a vastly more efficient working substance for the heat-engine at such temperatures and pressures than we are led to consider it from our knowledge of its properties under the now usual conditions of its use.

The author, writing at a date subsequent to that (April, 1877)

of the paper, adds that Mr. J. C. Hoadley has forwarded the results of experiments made upon a very "quick-running" engine to determine the value of the exponent x in Rankine's formula $P\,V^x = C$, and found $x = \frac{5}{4}$, or $x = 1.247$ which is taken as evidence of the greater accuracy of Zeuner's theoretical determination ($x = 1.33$) as given by McCulloch, and as indicating the possibility of the practical realization of this new type of engine. Were Rankine's determination correct, it is considered that such realization would be probably impossible.

ABSTRACT OF STATEMENT OF THE EXTENT AND CHARACTER OF THE WORK OF THE UNITED STATES BOARD APPOINTED TO TEST IRON, STEEL, AND OTHER METALS. By ROBERT H. THURSTON, of Hoboken, N. J.

THIS Board was appointed by the President of the United States, in accordance with the provisions of Section 4, of "Act making Appropriations for Sundry Civil Expenses of the Government, for the fiscal year ending June 30, 1876, and for other purposes." approved March 3, 1875.

It is instructed to determine by actual tests the strength and value of all kinds of iron, steel and other metals which may be submitted to it, or by it procured, and to prepare tables which will exhibit the strength and value of such materials for constructive purposes.

The Board consists of the following named members: —

President — Lt. Col. T. T. S. Laidley, U. S. A.; Commander L. A. Beardslee, U. S. N.; Lt. Col. Q. A. Gillmore, U. S. A.; Chief Engineer, David Smith, U. S. N.; W. Sooy Smith, C. E.; A. L. Holley, C. E.; R. H. Thurston, A. M., C. E., *Secretary*.

The Board organized under the General Order issued by the President immediately after the passage of the law creating it, meeting at Watertown, Mass., in April, 1875. The Board at once proceeded to plan an exceedingly comprehensive scheme of work, intrusting each investigation to a Committee — usually consisting of three members — and distributed the greater part of the amount

allowed by Congress "for the expenses of the Board" among these Committees, for use in defraying the cost of making researches.

These Committees were :—

(A) On Abrasion and Wear. *Instructions:* — To examine and report upon the abrasion and wear of railway wheels, axles, rails and other materials, under the conditions of actual use.

(B) On Armor Plate. *Instructions:* — To make tests of Armor Plate, and to collect data derived from experiments already made to determine the characteristics of metal suitable for such use.

(C) On Chemical Research. *Instructions:* — To plan and conduct investigations of the mutual relations of the chemical and mechanical properties of metals.

(D) On Chains and Wire Ropes. *Instructions:* — To determine the character of iron best adapted for chain cables, the best form and proportions of link, and the qualities of metal used in the manufacture of iron and steel wire rope.

(E) On Corrosion of Metals. *Instructions:* To investigate the subject of the corrosion of metals under the conditions of actual use.

(F) On the Effects of Temperature. *Instructions:* — To investigate the effects of variations of temperature upon the strength and other qualities of iron, steel and other metals.

(G) On Girders and Columns. *Instructions:* — To arrange and conduct experiments to determine the laws of resistance of beams, girders and columns to change of form and to fracture.

(H) On Iron, Malleable. *Instructions:* — To examine and report upon the mechanical and physical proportions of wrought iron.

(I) On Iron, Cast. *Instructions:* — To consider and report upon the mechanical and physical properties of cast iron.

(J) On Metallic Alloys. *Instructions:* — To assume charge of a series of experiments on the characteristics of alloys, and an investigation of the laws of combination.

(K) On Orthogonal Simultaneous Strains. *Instructions:* — To plan and conduct a series of experiments on simultaneous orthogonal strains, with a view to the determination of laws.

(L) On Physical Phenomena. *Instructions:* — To make a special investigation of the physical phenomena accompanying the distortion and rupture of materials.

(M) On Re-heating and Re-rolling. *Instructions:* — To observe and to experiment upon the effects of re-heating, re-rolling, or otherwise re-working; of hammering, as compared with rolling, and of annealing the metals.

(N) On Steels Produced by Modern Processes. *Instructions:* —To investigate the constitution and characteristics of steels made by the Bessemer, open hearth, and other modern methods.

(O) On Steels for Tools. *Instructions:* — To determine the constitution and characteristics, and the special adaptations of steels used for tools.

The above named Committees of the Board were appointed to conduct the several investigations, and the special researches assigned them, in the interval during which the regular work of the Board was delayed by the preparation of the necessary testing machinery, and during such periods of leisure as might afterward occur.

These investigations were expected to be made with critical and scientific accuracy, and were, therefore, to consist of the minute analysis of a somewhat limited number of specimens and the precise determination of mechanical and physical properties, with a view to the detection and enunciation of the laws connecting them with the phenomena of resistance to flexure, distortion and rupture.

The Board proposed to enter upon a more general investigation, testing such specimens as might be forwarded to the President of the Board, or such as it might be determined to purchase in open market, immediately upon the completion of the apparatus ordered, at which time circulars were to be published giving detailed instructions relative to the preparation of specimens for test, and stating minutely the information demanded previous to their acceptance.

At a succeeding meeting, the Board considered applications from manufacturers requesting that work should be done for individual benefit, and passed the following as indicating their views and intentions in this matter.

Whereas, This Board propose, as soon as practicable, to give metal-makers the benefit of its testing machines, and of a skilled experimenter, at a reasonable charge, as a means by which they may give publicity to the behavior of their metals under test; it is

Resolved, That this Board decline to publish the names of metal makers in connection with the experiments certified to by the Board.

Resolved, That this resolution is not to be construed as a refusal to acknowledge contributions of metals and other aid from makers; on the contrary, such services will be always gratefully and publicly acknowledged.

No work of this character has yet been done as the testing machine will not be erected and used until an appropriation for its use is made by Congress.

Immediately upon the completion of the organization and the assignment of researches to the Committees, these committees determined upon the details of their different schemes of work, and

the President of the Board, under his instructions, made a contract for a testing machine of a capacity of 400 tons in tension and compression, and sufficiently large to take in columns, or rods, 30 feet long. Of the $75,000 appropriated by Congress, over $50,000 was expended on this testing machine, its foundations, the building in which it was enclosed, a steam engine and boiler to furnish the power, and the cranes and other attachments to the machine.

The remainder was distributed to the Committees, and was expended by them and in defraying the travelling expenses of the Board.

The Committees sent out circulars asking assistance and coöperation from manufacturers, and from men of science, of the character of which the following will give a good idea, as well as of the nature of the information sought by the Board.

The Committee on Abrasion and Wear desired to receive from any reliable source such precise data and such information as might enable the Secretary to compile, in as concise and exact form as possible, a statement of the mode of deformation, the rapidity of abrasion, and the laws governing wear in any important typical or exceptional cases.

The executive officers of all lines of railway, might, it was suggested, render valuable aid by furnishing statements of the wear of rails per ton of transportation, specifying with care the original weight, the make, and the character of the rail, the total amount of transportation, the length of time occupied, and stating whether the rail finally broke or was removed. Specimens of rails remarkable either for endurance or for a lack of this quality, if sent to the Committee, would be useful by assisting in the determination of the chemical and other properties which most affect the value of the material under the stated conditions of use. Similar statistics and information in regard to the wear of wheels, axles and other parts of rolling stock and machinery, were said to be equally valuable. Engineers having in any instance noted and accurately recorded such data, were requested to transmit to the Committee copies of their memoranda.

The wear of journals under heavy loads, or at high velocities, as well as under ordinary conditions, is an important branch of the subject. When possible it was desired that the dimensions of the journal, the maximum, the minimum and the mean weight sus-

tained, and the velocity of rubbing or number of revolutions per minute should be given. The nature of the lubricant is an essential element; and its composition, the method and frequency of application and the quantity used, and the coëfficient of friction were asked, as also whether heating occurs, and the circumstances of pressure and velocity of rubbing surfaces. Peculiar instances of the behavior, or unusual expedients in the management, of bearings, if described accurately and concisely, were requested.

The wear of tools, under the various conditions of workshop practice, was another subject of investigation. Weighing the tools carefully before and after use, and weighing the amount of metal removed were considered the most accurate method of determining the rate of abrasion. The area of surface finished, and the area of the surface cut by the tool, rate of feed, etc., were to be accurately ascertained and stated. The description of the tool, its shape, method of operation, the kind of metal used in the tool, the temper adopted, the character of the metal cut by it, the velocity of the tool, and, where peculiarities of behavior were noted, a careful statement of them, as desired.

The power required to drive the tool can sometimes be readily determined, and such information was asked as being of great value.

The recent investigations of M. Tresca—*Memoire sur le Rabatage des Metaux*, etc.—was referred to as an excellent example of such research.

The Committee on Chemical Research announced their intention of making a series of determinations of the effects of carbon, phosphorus, silicon, manganese and other elements, upon the strength, toughness, elasticity and other qualities of iron and steel. The specimens were to be analyzed and subjected to tension, torsion, compression and other mechanical tests.

Makers of metal were requested to give a full description of the kind and make of raw materials, and of processes employed in the manufacture of the bars, and also of the size of the ingot or pile, the number of re-heats, and the extent to which hammering or rolling was employed in the reduction, to be kept in a reference book—each description having a number corresponding with that of the bar—all of which would be of great value.

Analyses, including color carbon tests—in case they had made them—were to be given in the above description, together with

their mechanical tests of the material furnished, with statement of shape and dimensions of specimens tested, were all to be recorded and furnished.

This Committee requested each maker to supply, where possible, one or all of the grades of steel in the following list:—

| | | |

tremes of temperature observed in northern latitudes, which, where exposed to wear or to breakage, afford valuable data. The character of the fracture and the texture of the abraded surfaces, as well as the statistics ordinarily collected, were to be noted. Specimens exhibiting peculiarities of behavior or appearance, and photographs of masses which it may not be convenient to forward, were asked as of real value. Where exact quantitative analyses of metals exhibiting unusual characteristics could be given, they were requested as aiding effectively in the determination of the causes of such peculiarities.

The statistics of well-managed railroads were expected to afford useful and reliable information. Rolling mills, producing rails and other forms of rolled iron which are tested by the drop, it was thought might be able to furnish more accurate statements of the effect of changes of temperature in modifying resistance to shocks.

Some experimental work had already been done in this field, and it was desired that the results of such researches should be communicated in as great detail and with as much accuracy as possible. Published monographs, references to papers published in scientific, engineering or other periodicals, and unpublished papers, were accepted as valuable contributions.

Assistance was asked by the committee in the endeavor to ascertain the character of the changes of the force of cohesion produced in the metals and their alloys by variations of temperature, to determine the mathematical expression of the law governing such changes, and to obtain such formulas, either exact or approximate, as would make these results conveniently and practically available to engineers and constructors.

Many experiments have been made by the rolling-mills engaged in the manufacture of wrought-iron beams, the results of which have doubtless been carefully recorded and tabulated. The Committee on Beams and Girders asked copies of such records and tables. Engineers, architects and manufacturers, have also made many experiments upon cast-iron beams and riveted wrought-iron struts and girders, the results of which were requested by the Committee.

It was considered desirable that information as full as might be obtainable, with reference to the constitution and manufacture of the iron used in making the pieces tested, should accompany reports of experiments, especially chemical analyses of the metal where these have been carefully made.

The proportions of the various parts of the samples tested were

to be exactly given; and in all riveted work the size and position of the rivets should be clearly set forth. In all cases, the modes of applying and measuring the strains to be stated.

Accurate cross-sections of the samples tested, drawn to scale, large enough to admit of reliable measurements, were desired as greatly facilitating a proper understanding and analysis of the results.

While the machinery ordered by the Board was in course of construction the Committee desired to collect information as above, and to make such experiments as seem practicable by the use of dead loads. For these experiments, and for those which were to be made when the machinery was ready for use, manufacturers were asked to supply such beams, girders and columns as they desired to have carefully and impartially tested.

The Committee on Cast Iron sought information relative to:—

First,—The strength of cast iron—tensile, compressive, transverse, shearing and torsional—under various conditions of quality, form and mode of application; phenomena of rupture; the forms of breakage occurring sufficiently often to suggest characteristic resistances; facts in regard to "steady strain and impact;" the "fatigue" of cast iron from long continued loads and strains, from frequently repeated vibrations, shocks or blows; practical methods of casting large, bulky masses or very small patterns; methods of making castings intended to resist strains, so as to secure freedom from sponginess and blow-holes; points to be observed in selecting one or more varieties of iron, with a view of attaining definite qualities of castings; methods for discovering imperfections in castings, etc.

Second.—Influence of heat, and of slow or rapid and sudden cooling; chill hardening; refining; crystallographic forms; physical or graphitoidal mixtures of carbon; presence of silicon; effects resulting from changes in the arrangement of molecules from any cause; molecular tension affected by chemical changes; corroding influences when in continued contact with fresh or salt water, or gases; appearances leading to a definite knowledge of quality or character, etc., etc.

The Committee on the strength, etc., of metallic alloys, endeavored to obtain records of all experiments which have hitherto been made in that direction, and to secure such exact information as might assist in further researches.

It was stated as desirable that such records should embody a statement of the precise chemical constitution of each alloy examined, as obtained both by synthesis and subsequent analysis. Its specific gravity, specific heat, conductivity, its combining number, and the relation of its chemical constitution to the series of similar compounds produced by alloying the elements in the

proportions of chemical equivalents, were to be stated whenever possible. A few thoroughly well studied examples were said to be of more service than a large number of isolated determinations of single facts.

It was further desired that the ultimate strength, the elastic limit, the modulus of elasticity, the ductility, resilience, homogeneousness, hardness and other mechanical properties of the specimen should be ascertained and accurately stated.

Where only a part of this work could be done by the investigator, the Committee assumed charge of the remaining portion of the research, when the alloy could be furnished in proper quantity and form.

References to published accounts of similar works and monographs on any branch of the subject were asked.

The Departments of Physics and of Chemistry in the various colleges and universities might probably be able to render valuable aid, and their coöperation was earnestly requested.

The Schools of Engineering are in a position to assist this Committee very effectively, and their contributions were gladly accepted.

Specimens of alloys for test by the Committee were to be accompanied by a statement upon proper blanks of their precise constitution, and such information as it might be possible to give, with an account of peculiarities known to distinguish the alloy, and of the special object supposed to be attainable by the investigation.

Where possible, it was required that one or more specimens should be furnished of each of the specified kinds, and of a definite form and dimensions, which were given on application.

Other committees set about their work in a similar way, and the Board thus inaugurated a scheme for the investigation of the strength and physical characteristics of the "useful" metals which was more comprehensive and more thoroughly organized than any ever before attempted.

The Board received very little information from any class to whom the above described applications were addressed.

Some valuable communications were, however, received, and the Secretary has translated a number of papers received from France and Germany, and containing valuable matter, which papers will be printed, should Congress so direct, with the reports of the Board.

Several committees at once entered upon the most important of

the investigations offered by the Board and have continued their work up to the present time. Other Committees decided to await the completion of the great testing machine ordered before beginning the heavier work assigned them. In one or two other cases, committees began working, but ceased when it seemed probable that Congress would not sustain the Board in its work, and when appropriations were refused by the House Committee.

In several cases, the want of funds has not prevented good work being done, however.

The Bureau of Equipment of the Navy Department permitted the committees on wrought iron and on chain cables to do their work on the testing machine at the Washington Navy Yard, and allowed those committees to make use of an extremely valuable, very extended and quite expensive, series of tests there made for that Bureau, thus placing in the hands of the Board invaluable material from which to deduce most important facts and principles.

When it seemed probable that the interruption of the operations of one of the most important committees must occur, in the absence of congressional support, private business firms volunteered to furnish the material needed for their work, although the expense was certain to be considerable; and when the preparation of a report was likely to be interrupted in consequence of lack of funds needed in making the calculations, the drawings and the diagrams required to illustrate it, a gentleman whose appreciation of its value was evidently greater than that exhibited by our representatives in Congress offered to pay the cost.

The work done to date may be summarized, as reported by a Committee of the American Society of Civil Engineers, as follows: —

The general plan is announced, and is to be a thoroughly scientific and systematic exploration of the field assigned to the Board. Materials are not only to be tested and the results stated as those derived from the examination of a metal of a conventional denomination, but the test-piece, in each case, will usually be examined to determine how far peculiar qualities are attributable to peculiarities of chemical composition and of physical structure.

A chemical laboratory has been established at Watertown Arsenal, and the chemist to the Board, Mr. Andrew A. Blair, formerly of St. Louis, has already done a large amount of work upon irons, steels and other metals and alloys, and the specimens thus examined as to composition are subjected to the several kinds of mechanical stress to discover the effect of composition in determining resistances to distortion and rupture.

A series of steels is in preparation under the direction of the Committee on Chemical Research, in which other elements being retained constant in amount, the carbon varies regularly from 0 to 2 per cent.; another series, with carbon uniform, has silicon in varying proportions; another set varies in phosphorus, still another in sulphur, and another series is variable in manganese. In each series, one element varies between wide limits, while the other elements are all retained as uniform as possible. The work of the melter is checked by analysis, and the specimens are then tested mechanically. This investigation, greatly as it has been needed, has never before been even attempted. It is considered by the members of the Board as likely to prove the most valuable research ever made in this direction, and the only one in which the chemist and the engineer have ever systematically joined forces in making such an exhaustive and scientific investigation.

The Committee on Abrasion and Wear is engaged in collating information relating to this subject, and is making experiments at the Stevens Institute of Technology on the abrasion and wear of the metals, and on the effect of lubrication in reducing it. The Chairman is fitting up machinery and apparatus for use in further investigation. A considerable amount of work has been done.

The Committee on Armor Plate is engaged in collating from domestic and foreign sources information that may be valuable in determining the qualities requisite in armor plate, and how those qualities are to be secured. The records of the Army and Navy Departments, and of the British Admiralty are considered to be the most promising mines of information to be worked by this Committee.

The Committee on Chemical Research has charge of the chemical work referred to.

The Committee on Chains and Wire Rope is endeavoring to determine the character of metal best adapted to making chain and rope, and the proper form and proportion of link, and is working up the data which have long been collecting at the Navy Department. The later experiments of Com. Beardslee are extensive in range, and that officer is collating and arranging the records for the use of the Board. Further experiments will fill up any hiatus that may be detected. The Navy Yard at Washington, where this work is going on, affords peculiar facilities not only for testing, but for making chain cable of any desired size, form of link or quality of metal.

Work already done there by the Chairman of this Committee has revealed serious defects in accepted tables of sizes and strength, and has indicated the rate of variation of strength, with variation of size of bar, and permitted the formation of a new and trustworthy table.

The Committee on the Corrosion of Metals is investigating the conditions affecting the corrosion of metals in use. Some information has been collected, some chemical work has been done, and much more work is projected for the ensuing year.

The Committee on the Effects of Temperature has planned an extended

investigation of this subject, and is gathering information from various sources. The research will be commenced by the Chairman during the coming year, if the Board is sustained in its work. The Chairman has already collated all published information accessible in periodical literature,—has made some preliminary experiments, and is receiving some information from various directions.

The Committee on Girders and Columns has a plan of operations which includes elaborate investigations of the strength of materials in columns and girders of various forms and proportions. This is the most formidable and expensive of the researches to be undertaken by the Board, and the power and accuracy of the 400 tons testing machine will be fully taxed in this work. The Committee is receiving the cooperation and active aid of some of the largest manufacturers of beams and girders in the country. The results of experiments already made have been communicated to the Committee by the engineers of railroads and of mills, and in other cases important and costly experiments have been undertaken by private incorporated companies (the Board has been invited to be present and to assist in the work if it should seem desirable); these results are to be given the Board, such sizes and proportions as the Board may desire to test are to be made, and all necessary labor furnished without any expense to the government. Bridge builders, civil and mechanical engineers and architects are corresponding with the Board on this subject, and the greatest interest, and a most gratifying public spirit are said by the members to be met on all sides. The Committee itself has done considerable experimental work,—principally at Buffalo,—the material having been, in some cases, gratuitously furnished by manufacturers of rolled beams.

The Committee on Malleable Iron has collated a large mass of valuable information, and the records of a great number of experiments, and, among other important matter, has obtained an extensive collection of experimental determination of the effect of time upon the elevation of the elastic limit by strain, during periods varying from a few seconds up to a year. The variation of quality due to differences of size and form of section of the bar and the modification of strength, ductility and resilience are under investigation. The Chairman of this Committee is also determining the influence of proportions of test-pieces upon their ultimate resistances.

The Committee on Cast Iron is pursuing a course similar to that of the Committee on Malleable Iron, with similarly promising results.

The Committee on Metallic Alloys has made an investigation of the strength and other properties of bronzes, which may be taken as typical of the kind of work to be done by the Board.

Several series of copper-tin alloys were prepared, varying in some cases by regular percentages, and in others by chemical equivalents, and were cast in bars of 1-inch square section and about 28 inches long. Their temperatures of fusion were taken at casting, and some were cast in sand, and others in an iron ingot mould. The weighing was carefully done in a Coast Survey balance, in the Physical Laboratory of the Stevens Insti-

tute of Technology. A set were reserved for the determination of the coëfficient of expansion, by Dr. Mayer. The others were broken by transverse stress, one set by dead loads, and others in the transverse testing machine of the Mechanical Laboratory, and deflections and tests were recorded to the fourth place of decimals, in inches, and also in meters with equal precision. The logs were made up, and the results were also laid off graphically. The curves revealed some peculiar and important facts. The fractures were photographed and, where peculiar, were reported upon by Prof. Leeds, the chemist and mineralogist of the Institute. From the data obtained, the coëfficients of elasticity were calculated and recorded.

Complete sets were next broken by tension, and the results recorded and worked up as with the transverse tests, and the records and curves compared, and a series of compression specimens were made up as companion test-pieces.

The full series was finally tested in the autographic recording machine and, from the strain-diagrams, their strength, elasticity, ductility, resilience and homogeneousness were deduced, and the law of variation worked up graphically. The effect of strain in elevating the elastic limit was observed.

All specimens were examined by the chemist, and a comparison made between the proportions by mixture and composition in the bar which exhibit the loss of metal, and to some extent, change of physical character, produced by melting and casting. Some curious and interesting scientific facts are revealed by the research, and a new mineral, consisting of stannic acid with a trace of copper, in magnificent needle-shaped crystals was produced in some cases, which has been subjected to examination and analysis by Prof. Leeds.

A determination of specific gravities of the metals as purchased, as cast and as compressed mechanically, and in mass, and in a state of fine division, concludes this research.

A similar research is in progress, under the direction of this Committee, by Prof. Thurston, its Chairman, which is intended, also, to be as complete and accurate an investigation of the copper-zinc alloys as the resources at command will permit.

Before entering upon this work, the Chairman collated all published material bearing on the subject, and a preliminary report of about one hundred pages embodies the most important facts previously determined, and contains the bibliography of this subject of copper-tin alloys. This work was supplemented by making graphical records of the experimental work of Mallet, Mathessen, Calvert, Johnson and others on the conductivity for heat and electricity, and the specific gravity and other properties of copper-tin alloys, as had been examined by them. It was the intention to profit by facts already acquired by acknowleged authorities, to complement them by the new investigations, and to avoid useless repetition of work involving serious expenditure of time.

This paper is itself regarded as exceedingly valuable, and particularly

to the mechanical engineer, as it is the first time that these earlier researches have ever been collected and put in an accessible and compact form.

A similar preliminary research is made to preface the examination of the copper-tin-zinc alloys, and the same plan will be pursued throughout.

The Committee on Orthogonal Strains is planning a series of experiments to determine the laws of the resistance of materials under simultaneous stresses acting in rectangular directions, as in the case of a rod subjected to torsional or shearing simultaneously with tensile or compressive stress. The subject has been entirely unstudied up to the present time.

The Committee on Physical Phenomena is preparing to seek for the phenomena induced by stress in the various physical modes of energy, as the development of magnetic, electric and thermal actions. The fact of the development of heat and electricity has long been known, but no systematic or scientific investigation has ever been made in this direction.

The Committee on Steel produced by Modern Processes is working with the Committee on Chemical Research. It is collating also the vast mass of material available and will endeavor to make a report which shall be of great and permanent value.

The Committee on Re-heating and Re-rolling is to test iron, etc., in the several stages of manufacture; refined and unrefined, and to observe the effects of successive re-heats, of re-working and rolling, to determine, if possible, what amount of working is demanded by different irons, and what are the temperatures which will practically give the best results.

The Committee on Steel for Tools is making an extended series of experiments at the Washington Navy Yard to determine the value of various steels for tools. A large collection of steels is made; their composition is determined, and they are there carefully tested by setting them at work — turning, planing, boring and chiselling — and their behavior and their composition being thus ascertained it will probably be easy to learn the chemical and physical characteristics of the best tools. The names of makers are of no importance in this investigation, and are not to be reported. The Board, in all its work, will avoid reference to makers of material in any way that may injure any manufacturer directly or indirectly. Scientific knowledge of directly practical value, and engineering facts and figures, solely are sought.

Since that Committee reported, several of these investigations have been completed, and the reports are now completed, or are in preparation.

About 150 steels have been completely analyzed, and the Committee on Chemical Research are making the tests of their physical and mechanical properties for comparison. This work may probably never be completed as the Committee have not sufficient funds.

The Committees on Wrought Iron, or Re-heating and Re-rolling,

and on Cables, make a common report which is completed. In this report, the information above outlined is carefully collated, and it is expected that the facts and data given will be valuable to all makers and users of iron, and especially those portions which analyze and describe the effects of the several details of processes of making and rolling iron, the effects of various kinds of strain, and the results of the attempts made to determine the best method of making cables for large vessels, and to determine how uniform strength can be secured in iron of different sizes in the bar, and how to make large masses equally strong with small pieces.

The report of the Committee on Metallic Alloys—containing 600 pages of manuscript with illustrations, tables of date and diagrams—is completed so far as it relates to the copper-tin alloys. The work on the other alloys, copper-zinc and copper-tin-zinc, is done, and those reports are in preparation. The result of all this work is comprised within the smallest possible compass, in the small model here exhibited[1] on which the strength of all possible alloys of these three classes is shown by ordinates measuring 25,000 pounds per square inch, for each vertical inch of the ordinate. On this little triangular plate, every possible composition of the three metals, copper, zinc and tin—whether combined two or three together—is represented. Similar models may be made to represent the ductility of all these alloys, or the resilience, or the elasticity, or any other quality which has been determined. It will be observed that we have here a beautifully accurate method of ascertaining maxima. It will be seen when the model is studied that a maximum occurs when a composition containing nearly the proportions of Muntz metal with about two or three per cent. of tin is found, and it will be seen that a very slight deviation in either direction from this exact mixture reduces the strength immensely. In one direction a change of but a few per cent. makes a metal so brittle that it falls to pieces in the mould. It is also seen that the strength of certain alloys can be calculated from their composition, a very simple formula giving the range of compositions of maximum strength:—

Thus, $Z + 4\ Sn = M$ may be taken as one, in which Z is the percentage of zinc, Sn that of tin in any triple alloys, and M the

[1] See Illustration accompanying paper "On a New Method of Planning Researches," etc.

total which give a composition of maximum strength. That strength is not far from

$$40{,}000 + 500\ Z = \text{Tenacity}$$

where Z is the percentage of zinc, in those alloys of maximum strength. Again for copper-tin alloys of from 0 to 20 per cent. tin, the tenacity is not far from

$$30{,}000 + 1{,}000\ Sn = T$$

where Sn is the percentage of tin present, the alloys having been well fluxed and the casting perfectly sound. For brass, the formula would be approximately within certain limits,

$$30{,}000 + 500\ Z = T.$$

The other Committees than those named have not reported, but it is hoped that, if properly supported by Congress, they will all have valuable information to give.

There seems to have been no opposition to the continuance of this Commission inside or outside the halls of Congress, except in the House Committee on Appropriations, where some members have not become convinced that the work of the Board is as important in its way as that of the several Bureaus of the Department of the interior, including the Patent Office; that it is the only way in which the mineral resources of the country and the metal industries can be effectively developed, and that in no other way can the engineers who design, and the manufacturers who build all works in which metal is used, obtain that exact knowledge of their materials which is essential to the security of their constructions.

It is, to a certain degree, a satisfaction to be able to report that, although our own legislators have shown so little appreciation of the importance of a national work like this, those of other countries have been quick to take the hint given them, and that inquiries have come from several directions respecting the organization, and the methods of work of the Board which indicate that similar commissions will probably be organized in other countries, and that, so far as the scientific results aimed at are concerned, we may hope to see good work done, although we must forego the credit of having ourselves done that work, and notwithstanding the fact that the commercial benefit hoped for is the direct consequence of the work of our own Board.

It is greatly to be regretted that the business and scientific men of the country have permitted their influence to become of so little weight at the national capital. The work of this Board has been demanded by nearly all of the principal organizations of business men, by the scientific schools and by the faculties of many of the colleges of the country, and memorials have been presented in Congress, asking liberal support for the Board, from the American Iron and Steel Association, the American Society of Civil Engineers, the American Institute of Mining Engineers, the several institutes of technology, and from other institutions; but our representatives have taken far less interest in the matter than should have been expected, and the House Committee on Appropriations have actually introduced into their last appropriation bill a provision for the discharge of the Board at the end of the present fiscal year.

ON A NEW METHOD OF PLANNING RESEARCHES AND OF REPRESENTING TO THE EYE THE RESULTS OF COMBINATION OF THREE OR MORE ELEMENTS IN VARYING PROPORTIONS. By R. H. THURSTON, of Hoboken, N. J.

I. THE writer has lately been called upon to conduct, in the mechanical laboratory of the Stevens Institute of Technology, among other researches, a series of investigations of the mechanical properties of the more important alloys of the useful metals.

The most extended and important of these investigations was made at the request of a Committee of the Board appointed by the President of the United States, by direction of Congress, to determine by test, the values, for purposes of construction, of iron, steel, and other useful metals and their combinations. This "committee on the metallic alloys" was directed to report upon the "characteristics of alloys and the laws of combination."

The research intrusted to the writer was the study of the met-

als, copper, zinc, and tin, and their innumerable combinations. The planning and the prosecution of the examination of alloys composed of two metals, as copper and tin, or copper and zinc, was attended with no special difficulties. A series of alloys of each of these pairs of elements was made, containing from one hundred per cent. copper, at the one end, to one hundred per cent. tin, or one hundred per cent. zinc, at the other end of the series, and varying by two and a half per cent. from one end to the other. The moduli of rupture by transverse stress, by tension, by compression and by torsion, the moduli of elasticity, the density, homogeneousness, the resilience and other properties of all the metals in these series were determined and recorded. The results of each test of each metal were then plotted, and the curve formed by uniting the points thus laid down represented the law of variation of distortion of the piece with variation of the distorting force. Such curves may usually be represented, also, by equations which are the mathematical expressions of these laws.

Another set of curves was formed by plotting the results of tests of the metals in series. The ordinates of one of these curves, for example, measured the tenacity of the alloys of the series which it referred to, and the abscissas measured the corresponding position of the alloy in the series. The abscissa of a certain point would thus indicate that the alloy represented was midway in the series, containing fifty per cent. of each metal, and its ordinate would show its tenacity to be, say 40,000 pounds per square inch of original section. These curves were curiously unsymmetrical and could not be represented by any simple equation; they, however, are none the less valuable as graphical representations of the properties of the alloys as grouped in series. An elaborate report upon this work has been prepared by the writer for publication by the Board from which report the constants thus determined may be obtained.

The properties of any series composed of variable proportions of two elements may thus be readily determined and represented; the curves representing the results are also representative of the properties of all possible alloys of the two metals.

II. To determine the properties of all the infinite number of possible combinations of the three metals in triple alloys of copper, zinc, and tin seemed, at first, a far less simple matter. It was proposed to test, first, a set of these alloys differing by ten per cent.;

and the following series was made up to be tested in tension, torsion and compression, and by transverse stress:—

COPPER.	ZINC.	TIN.	COPPER.	ZINC.	TIN.
10	10	80	30	40	30
10	20	70	30	50	20
10	30	60	30	60	10
10	40	50	40	10	50
10	50	40	40	20	40
10	60	30	40	30	30
10	70	20	40	40	20
10	80	10	40	50	10
20	10	70	50	10	40
20	20	60	50	20	30
20	30	50	50	30	20
20	40	40	50	40	10
20	50	30	60	10	30
20	60	20	60	20	20
20	70	10	60	30	10
30	10	60	70	10	20
30	20	50	70	20	10
30	30	40	80	10	10

It was not sufficient, however, to test this series and simply to record the results. It was necessary to determine the law connecting the mechanical properties with the composition of the alloy, to determine whether there were abrupt variations of properties, to detect points of maxima and minima and to so accurately determine these points, that any one studying the results of the work should be able to say, with confidence, what would be the precise character of any possible alloy of the three metals which he might propose to make.

It seemed to the writer evident that the only system of collating results which would probably enable him to attain these essential objects was some graphical method. To represent with satisfactory precision, completeness and intelligibility, a series of researches on the character of triple alloys of all desired proportions, appeared, at first, a most difficult, if not insolvable problem. A very perfect and most satisfactory method was, however, finally devised:—

In any triangle, as at A, figure 1, let fall perpendiculars upon the three equal sides. The area of the whole triangle B, C, D, is measured by the product of the altitude, C E, by one-half the base, B D. Draw lines A B, A C, A D, to the vertices of the

triangle, thus forming three smaller triangles, the sum of which equals, in area, the original triangle. We now have: C E × 1–2 B D = A F × 1–2 B D + A G × 1–2 B C + A H × 1–2 C D; or, the sides of the triangle being equal, C E × 1–2 B D = (A F + A G + A H) 1–2 B D. Hence, A F + A G + A H = C E.

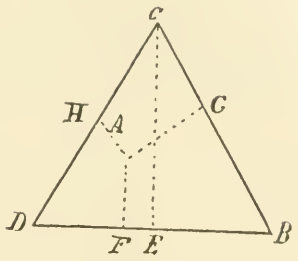


Figure 1.

But the area of the whole triangle may be conceived to represent a triple alloy composed of the three components in proportions represented by the areas of the three several small triangles which together make up its total area. But these smaller triangles have areas proportional, as has just been seen, to their altitudes, A F, A G, A H, the proportions in which the three metals are combined to form the given triple alloy may, therefore, be measured by the ratio of their representative triangles to the whole triangle in area and in altitude. Then, dividing the height of the large triangle into one hundred equal parts, the altitudes of the small triangles, measured in the same units, will represent the percentages of the three elements in the given alloy.

A moment's thought will show that we have here precisely what is needed. Every point in the triangle thus represents some certain triple alloy; there is no possible triple alloy which has not its representative point in our triangle. We now have before us a field which exactly defines our research, and we may attempt its exploration with a clear understanding of what is to be done. Its topography may be studied as systematically and completely as that of any other territory of which the exact boundaries have been determined and marked out.

Although it is entirely beyond our power, even if we desired to do so, to examine every point in this great field and to make every one of the infinite number of alloys here represented, and then to determine the principal characteristics of each by direct experiment, we may arrive at the same result, as nearly as we may choose, by the same system which we adopt in all topographical surveys. Let it be proposed to discover what is the strength of all the possible alloys of copper, zinc and tin: lay out, within the

principal figure, a series of concentric triangles, as in figure 2, of which the vertices are placed at distances representing ten per cent., twenty per cent., thirty per cent., and so on, from the vertices of the large triangle; select along the sides of these triangles excluding the exterior figure, points ten per cent. apart for examination. These points will be found to represent the list of triple alloys which has already been given above. The points taken in the outline of the principal triangle represent the double alloys of copper-zinc, copper-tin, and tin-zinc, in proportions also varying ten per cent. They are alloys in each of which the proportion of the third element of the variable triple combination to be studied has become zero. Now, determine the strength of each of these alloys, and, upon the point which represents it in the figure, erect a perpendicular having a height proportional, on any convenient scale, to that strength. Having completed this work, we have, upon our triangular base-plane, a forest of verticals, each of which is an ordinate of a point in a surface which may now be conceived to pass through them all. Curves of sections, running in any desired direction across this field, may now be made, and they will be the graphical representations of the law which connects cohesion and composition in the series of alloys so selected; just as the surface is representative of the law for all possible alloys of the three metals selected for experiment.

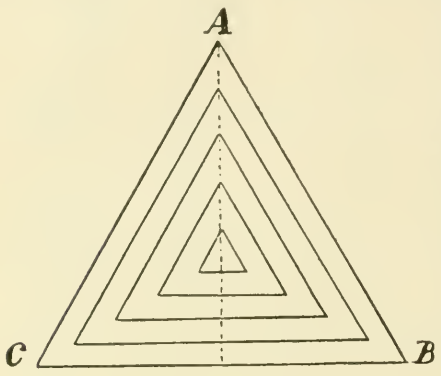


Figure 2.

Lines connecting points of equal altitude may be drawn, as on topographical maps, and, on these lines of alloys of equal strength, that which meets any given requirement in other respects, as in cheapness or in ductility, may be selected. The same method will evidently answer equally well in the representation of any other quality, as the resistance to transverse fracture, to shearing forces, to compression, or in the exhibition of ductility, elasticity, or of

the values of the moduli of elasticity or of resilience whether elastic or total.

In many cases it would be found that, at sharp culminations, in points or lines, forming peaks or ridges in our topography, it would be necessary to take another set of points nearer together, and thus to feel out with greater exactness the sudden changes of result which follow the operation of the discovered law at such "critical" points or lines.

The result of an investigation, such as has just been described, may be very beautifully exhibited to the eye by making a *model* of

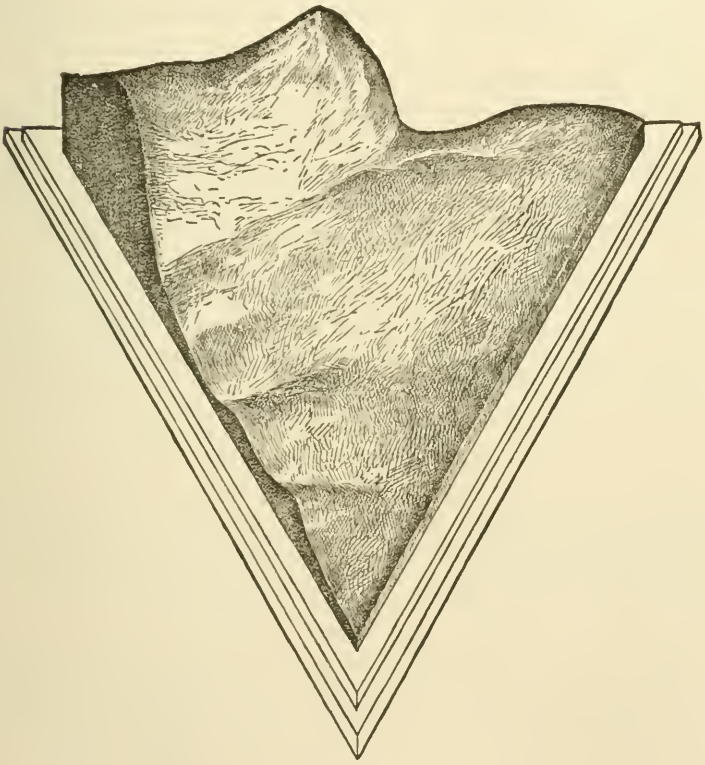


Figure 3.

the surface thus determined. In carrying out these researches the writer has found the following plan perfectly satisfactory :—

Lay out a triangle, as above described, upon a surface of sheet brass. At the points at which determinations have been made, erect wires of which the lengths have been made carefully proportional to the ordinates of the representative surface at those points, screwing them firmly, or otherwise fixing them, in their places. When all the wires are in place and are found to be of the exact length required, place bits of board along the outside to form the boundaries of the triangle, and pour in plaster of Paris until the wires are all covered. When the plaster has set, remove the boards and carefullly cut away the upper part of the plaster, working carefully down to the tops of the wires, just exposing their points. The surface thus produced is a model of the strength, or other quality represented, of all the alloys.

Mr. M. I. Coster has prepared for the writer such a model of the cohesive strength of the alloys of the three metals, copper, zinc, and tin, as determined for the United States Board appointed to test metals, and a photograph has been taken from which the engraving, figure 3, has been made. A full account of the research has been prepared for publication and presented to the Board. It will probably be printed by Congress and the constants determined may then be obtained. The writer is not at liberty to give them here, and the illustration is presented simply as showing well this method of investigation of such problems, as it has been practised by him.

ON THE PROPER MOTION OF THE TRIFID NEBULA, = M. 20 = G. C. 4355, etc., R. A. 17h. 53m. 51.8s.; N. P. D. = 113° 1′39.9″; 1860.0. By EDWARD S. HOLDEN, of Washington, D. C.

[ABSTRACT.]

THIS abstract of the original paper[1] is presented, as that paper consists largely of tables of star positions, detailed observations, etc., which cannot be intelligently followed without the aid of copies of the various drawings, which are not now at hand. It will be sufficient to indicate the contents of the various sections of the paper, and to summarize the results obtained, leaving the proofs of the results here set down to be gained from the paper in full.

[1]The full paper is printed in Amer. Jour. Sci. for Dec., 1877.

The first section deals with *early observations of the nebula*, giving those of Messier (its discoverer) [1764] Sir William Herschel [1784–1811], Sir John Herschel [1826–1833], particularly in regard to the situation of the remarkable triple star Sh. 379 with respect to the three surrounding nebulosities A, B, C (so named by Mason), which together make up the Trifid Nebula and give it its name. The conclusion reached in this section, which rests on the most positive assertions of the various authorities, several times repeated, is

A. "*From* 1784 *July* 12, *to* 1833, *this triple star was centrally situated between the three nebulosities.*"

The next section details the observations of Mason and Smith [1839]; these are followed by the observations of Sir John Herschel at the Cape of Good Hope [1837], and those of Lassell [1862–4], Langley [1866], Trouvelot [1874], and myself [1874–1877].

The position of the nebulosity A *relative to the triple star* is the subject of the next section. Here, from each authority, five propositions (so to say) are deduced, and these are subsequently arranged in chronological order for purposes of comparison. The conclusion from these, which is conceived to be certain, is

B. *From* 1839 *to* 1877 *the triple star was not centrally situated between the three nebulosities, but was involved in* A.

In the next section we have *General Notes on the brighter portions of the Nebula*. The brighter portions only are considered, in order to avoid, as much as possible, the discrepancies arising from differences of instrumental power. In this examination, again, it was found convenient to derive a series of propositions (eleven in all) from each authority, which are afterwards collated and compared.

From these we find many marked discrepancies, most of which are referred to simple mistakes of drawing or description, due largely, no doubt, to the different telescopes, although all of these are consistent with the conclusions subsequently drawn. However, little or no weight is attached to most of them.

One case however we may cite. The northern well defined edge of nebulosity C in the J R. A. — 7s. is placed by

Herschel in $J\,\delta = -123''$.
Mason in $J\,\delta = -187''$—(measured).
Lassell in $J\,\delta = -73''$—(measured).
Trouvelot in $J\,\delta = -60''$.
Holden in $J\,\delta = -65''$—(measured).

MASON and HERSCHEL agree more closely than the above figures taken alone would indicate. MASON's figures too, are not derived from drawings alone, but depend upon the fact that the limit of the nebulosity has a $\Delta\delta$ about the mean of the $\Delta\delta$ of two stars whose positions were fixed by MASON. The measures of LASSELL and HOLDEN are equally definite. The conclusion here is, and it is supported by various circumstances detailed in the original paper, that the nebulosity which MASON placed in one position is now over $1'\ 30''$ of arc north of that position. This conclusion rests, almost entirely, on micrometric measures. In another case the space (A) which *precedes* the triple star about 7s. and which lies between the parallels $\Delta\delta = 0''$ and $\Delta\delta = -38''$ is according to

HERSCHEL: about the brightest portion of the nebula and continuous with B.

MASON: nearly equal to the brightest portion of the nebula and continuous with B.

LASSELL: totally free of nebulosity.

TROUVELOT: pretty bright and part of B.

HOLDEN: bright, but separated from B by a faint channel (too faint for TROUVELOT's telescope to show unless under good circumstances).

Comparing A and B there are only three ways to reconcile the opposing facts.

a. The triple star has a large proper motion.

b. The nebula A has a large proper motion.

c. The nebula A is subject to decided changes of brilliancy.

The first point will be settled by meridian observations kindly undertaken by Prof. EASTMAN, U. S. Navy, with the Washington Transit-Circle. Equatorial comparisons with neighboring stars indicate no relative motion since 1839.

If, as is probable, the proper motion of the star is small, there remain two alternatives to choose between.

These inferences A and B rest on undoubted authority, and they are supported only by evidence where no doubtful points have arisen.

It, therefore, appears to me to be a just conclusion that *the evidence as recorded with regard to this nebula indicates marked changes of position and brilliancy during the period* 1784–1877.

I have, in my own mind, no doubt that the *evidence as recorded*, if thoroughly examined by any competent person, will lead to the

same conclusion. The examination of many drawings of nebulæ has however led me, in common with others, to the conclusion that too great care cannot be exercised in interpreting drawings and observations of this class. The principal question is as to the goodness of the evidence itself, and I have inquired what evidence must be *rejected* if we are to suppose the nebula to have been *un*changed between 1784 and 1877. Inference A rests mainly on statements of Sir JOHN HERSCHEL, which could not possibly have been made more definite. Inference B is undoubtedly correct.

The *essential* evidence with regard to the other points is that of MASON, LASSELL (two independent drawings) and my own, the other drawings being corroborative but not *essential*. I am satisfied that MASON's work is correct. LASSELL's two drawings (by two different hands at different times) agree with one another, and at any rate no series of drawings deserves more weight than that made by LASSELL with his four-foot telescope at Malta. My own work, though not done in the best atmospheric circumstances, I am satisfied is, on essential points, correct. I am, therefore, of opinion that the conclusion above ought to stand and that we have evidence of change in this nebula, and that it deserves the attention of astronomers.

IMPROVEMENT IN USE OF REFLECTING GONIOMETER. By HARVEY W. WILEY, of Lafayette, Indiana.

MANY chemists, who are provided with the ordinary form of reflecting goniometers, do not have their students use it on account of the difficulty of adjusting the crystal. To remove this difficulty I have made use of the following device: (Fig. 1).

At the movable axis, E, is attached a piece of brass plate bent into the form of a quarter of a circle E D.

To the central part of the axis, C, of the instrument, a fine platinum wire, silk fibre or hair, is attached. This is fastened to the brass strip at F, and by means of an adjusting screw can be brought exactly into the prolongation of the axis of the goniometer.

The crystal whose angle is to be measured is fastened in the usual way to the adjusting rod at H, and the edge around which the measurement is to be made, is brought up against the hair line and the adjustment is at once complete.

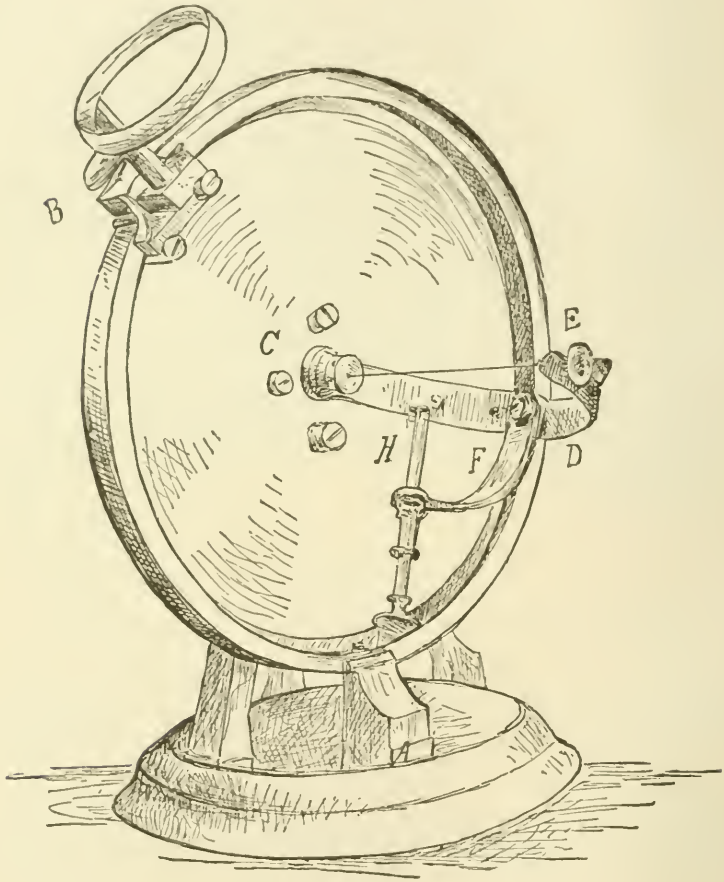


Figure 1.

By this simple device a great amount of time and trouble is saved, since without it the adjustment of the crystal can only be made by repeated trials, and it is then often the result of accident.

Another attachment which I have made to the Wallaston Goni-

ometer is represented in the figure. A circular piece of brass slightly larger than the graduated disk is fastened to the base of the instrument, at A. Freely movable around this is fixed a support, B, for the eye of the observer. This support can be fixed at any convenient point, by a set screw. The eye is thus kept steady during the process of measurement, thus avoiding a frequent source of error. In case the crystal is very small this support might be made to carry a magnifier. Many non-reflecting crystals can be worked in the reflecting goniometer by attaching thin scales of mica to the faces lying in the planes of the angle. A finely varnished surface may also be made to reflect well enough for purposes of measurement. Others engaged in this work will be able to devise still other means for the angular measurement of non-reflecting crystals.

I present this matter to the section chiefly for chemical use. Mineralogists, of course, in the final measurement of angles, resort to far more delicate methods. Students in synthetical chemistry should be taught to measure the angles of crystals which they may make, to help them in determining the system to which they belong.

With the goniometer arranged as suggested in this paper, students can reach very satisfactory results, and that too without consuming a great deal of time.

On the Wave length of the Blue line of the Spectrum of Indium. By T. C. Mendenhall, of Columbus, Ohio.

In Watts's Index of Spectra the wave-length of this line is given, on the authority of Müller as 4550, and on the authority of Thalen as 4509, the unit being tenth-metres.

An examination of the method used in the determination threw some doubt upon the result of Müller, and the following examination of the question was made with a view to a more accurate determination, which seemed to be desirable where so great a discrepancy existed.

Two independent methods were used, the first being the measurement of the wave-length directly from the diffraction spectrum of the element.

For this purpose was used one of Rutherford's gratings ruled upon glass, having 4320 lines to the inch. An electric spark was passed between two pieces of metallic Indium and the spectrum observed by the aid of a spectrometer, the objectives of whose collimator and telescope had an aperture of one and a half inches. With this arrangement it was easy to study the spectra up to the fourth order. A number of measurements made upon spectra of the first, second and third orders, result in a wave-length of 4516.

In the second method a prism having an angle of 64°—and being about two inches on the edge—was used, and in the telescope a micrometer eye-piece, a division on the head of the screw corresponding to the one ten-thousandth of an inch.

The following reference lines—lying near the blue line of Indium—were selected, and their distances from a fixed point taken in divisions of the micrometer screw. The wave-lengths are from Watts's Index:—

Magnesium	5183
Cadmium	4799
Cadmium	4677
Cadmium	4415
Strontium	4607

A spectrum curve was constructed, having for its ordinates the wave-lengths in tenth-metres, and for its abscissas divisions of the micrometer screw.

The position of the blue line of Indium was determined upon this curve, and a measurement of the corresponding ordinate gave a wave-length of 4511.

This result not being absolute, but based on determinations of other wave-lengths, I am convinced, after attaching proper weights to the observations, that the most probable value resulting from these observations is 4515 tenth metres.

After having completed the above determinations I learned of another measurement made within a year, by Messrs. Clayden and Heycock, in which the wave-length of this line is given as 4510. (Phil. Mag. Nov., 1876.)

These observations were mostly made and the curve was carefully constructed, by a student in my laboratory, Mr. C. C. Howard, and I am indebted to Prof. S. A. Norton for the specimens of Indium used in the work.

New Quadruple Objective for Astronomical Telescopes. By Ernst Gundlach, of Rochester, N. Y.

The dioptric telescope, the construction of which is based upon that property of light which causes it to change its direction, in a certain proportion, on passing from one medium into another of different density (for instance, from air into glass), consists for this reason in its simplest form, of two glass lenses of different foci placed in relation to each other, at the distance of the sum of their foci. Such an instrument would, provided the lenses had the correct and appropriate form (the hyperbolic), greatly exceed the performance of the best telescopes of the present day, if the (white) ray of light were a simple elementary unit, and did not consist, as is known to be the case, of different elements, each of them possessing the above mentioned power of refraction in a different degree. For such an instrument would, in such a case, not only be free from optical errors, but could attain within a very short length, and with full strength of light an immense magnifying power.

The construction of such (accurately hyperbolic) lenses, although appearing to superficial observation sufficiently simple, has however as yet not been accomplished. Still this technical difficulty would, perhaps, have been overcome long before this, if the perfection of the telescope had depended thereon exclusively, and if the existence of the above mentioned property of light did not in a still higher degree injuriously affect it by causing the so-called chromatic aberration, without the simultaneous removal of which the construction of hyperbolic lenses would have been of little consequence.

The improvement of the telescope had, therefore, in the first instance, to be directed towards the removal of the principal difficulty, the chromatic aberration; and this problem of Achromatism was happily solved by the invention of the combination of flint and crown glass, by which the construction of lenses, almost entirely free from the fault in question, was made possible.

By this invention, the problem of the construction of hyperbolic lenses for the purpose of further improvement of the telescope would have attained its fullest importance. It appeared, however, that in this new combination a superior means had also been obtained to correct the errors of form in lenses with spherical surfaces

(the construction of which presents no difficulties), so far as to make it possible to use such as a substitute for lenses of hyperbolic form.

While the neutralization of the *spherical* aberration can be attained principally by a proper *form* of the combined lenses, the neutralization of the *chromatic* aberrations depends rather on the correct *focal* relation of the same. As a means had been found in this way to correct both aberrations, the question now arose, what might be the most favorable proportions of form and foci, of the two lenses forming the new objective, and the greatest mathematicians devoted themselves to the computation of the radii of curvature according to which the lenses should be ground to form as perfect an objective as possible.

In this way originated the so-called achromatic double objective, and to Fraunhofer especially belongs the merit of having brought it to a high degree of perfection.

Valuable as this double quality of the flint-glass lens to correct *both* aberrations of the objective at the same time may appear at the first glance, on the other hand, on further examination, an important disadvantage, arising *from this very circumstance*, becomes apparent.

For although the rectification of the chromatic aberration is principally conditioned on the proper focal proportions of the two lenses, the form of the same, especially of the flint-glass lens, is by no means unimportant for this purpose, for it is rather a *definite* proportion of the forms of the two lenses, by means of which, under provision of correct focal relations, the most perfect correction of the chromatic aberration becomes possible.

This form, especially of the flint-glass lens, however, deviates considerably from that which would be the best for the correction of the *spherical* aberration, for while for the correction of the *chromatic* aberration the flint-glass lens should very nearly have the form equivalent to the minimum of its own spherical aberration, it must have for the most perfect correction of the *spherical* aberration, a very *considerable* negative spherical aberration.

This form of the flint-glass lens, the best to annul the spherical aberration will, however, with correct achromatism of the zone lying between centre and rim, chromatically *over*-correct the objective progressively toward the periphery, and *under*-correct the same progressively toward the centre.

From this it is easy to see that, under all circumstances, a substantial remnant either of the chromatic or the spherical aberration, or proportionally smaller remnants of both aberrations must remain; for the one can only be perfectly neutralized under circumstances conditional of a certain remnant of the other.

It is, therefore, clear that with an objective consisting of a crown and flint-glass lens, the correction of the aberrations cannot pass a certain limit.

This extreme limit, corresponding to the greatest possible perfection of the objective, will certainly be then obtained, when the unavoidable minimum remnants of both aberrations are equal so far as their injurious influences are concerned.[1]

Therefore, as demonstrated above, a further reduction of both aberrations in a double objective, is impossible, for the reason that *both depend on the same factor*, and a passing of the said limit is only conceivable in case the correction of the aberrations is effected by *separate* factors independent of each other. The flint-glass lens should therefore be reserved *exclusively* to its own legitimate purpose of correcting the *chromatic* aberration, without reference to the spherical aberration, and the latter should be neutralized by some other means, independent of the flint-glass lens.

It will be readily seen that in the finding of a means, which

[1] If we should admit that Frauenhofer's objectives were not perfectly corrected to the extreme limit, it cannot be doubted, notwithstanding, that such must have been very nearly the case. But even in such a case, the improvements made since Frauenhofer, in the construction of double objectives, could only have been very unimportant. On the other hand, if, as I am convinced, Frauenhofer very well knew how to give his objectives the best form possible, and as, so far as my knowledge goes, objectives for telescopes of more than two lenses have not as yet been successfully constructed, an actual improvement in this direction cannot be said to have been made since.

Modern opticians, however, have considerably shortened the foci of their objectives. It may be assumed, although not demonstrated, that these shortenings could only have been made possible by *a corresponding reduction of the aberrations*, for without the latter the shortening of the foci cannot be called an improvement. If, therefore, as we have just seen, the neutralization of the aberrations is only possible within certain limits, and such limits have already been reached by Frauenhofer (if not altogether, at least very nearly), the above mentioned reduction of the aberrations can only have been effected by an improvement in the material (the glass).

As this latter improvement, which has undoubtedly taken place, is, however, limited almost exclusively to a greater difference of the power of dispersion and refraction, leaving the important problem of the removal of the secondary spectrum still unsolved, a very high value cannot be attributed either to the advantages attained thereby; and I believe, therefore, and have found it confirmed by occasional observations, that modern opticians have carried their shortening of the foci of their objectives further than serviceable to the purpose, and that an actual comparison of such a modern telescope, at least a larger one, with one of Frauenhofer's, would result in favor of the latter.

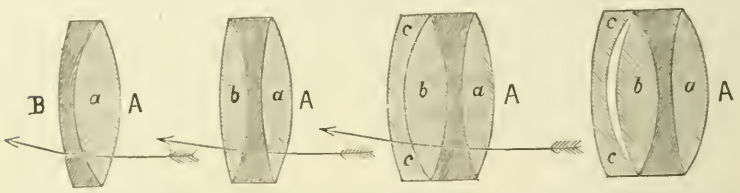
will enable us to correct independently the spherical aberration, a true and essential improvement of the telescope will be attained, because thereby the possibility is given for both aberrations far to transgress the above mentioned limit of correction, which is also the limit of performance of the objective.

Such a means, however, or rather an objective constructed with this view and on this principle, is the purpose of this article to describe.

The first question is: In what way must the double objective be altered if the flint-glass lens is to neutralize as perfectly as possible the dispersion of colors with*out reference to the spherical aberration?*

Let us presume the proportion of form of the two outer surfaces A and B of the double objective (Fig. 1)[2] to be such, that the rays coming from the side A, parallel to the optical axis suffer the mini-

Fig. 1. Fig. 2. Fig. 3. Fig. 4.



mum of spherical aberration which is the case when the refraction which the ray undergoes at the surface of entrance is equal in value of angle and in direction to that which it undergoes at the surface of exit.[3]

Now in this case the form of the flint-glass lens *for itself alone* deviates considerably from the above mentioned best form, as even the direction of the refraction for both surfaces is an opposite one, as will be easily seen by the figure. To improve the form of the flint-glass lens in such a way that the refraction at both surfaces takes place not only in the same direction (diverging from the axis) but in the same degree, without being obliged at the same time to alter the form of the exterior surfaces (in favor of the spherical

[2] For better understanding, the radii of curvature have been represented in this drawing much shorter than would be admissible in an objective for a telescope.

[3] Strictly speaking this is not the case for the whole extent of the lens, but rather only for a limited distance from the axis. This distance is for a lens of least spherical aberration a trifle larger than half the radius of the lens.

aberration), let us suppose the flint-glass lens to be flexible, the crown-glass lens, however, to be in a fluid state; let us further presume (for the purpose of preserving the outer form of the objective), both to be enclosed in a vessel of a corresponding inner form, so that the outer (convex) surface of the flint-glass lens fits close to the inner surface B of such vessel, and consider the rest of the space to be filled by the crown-glass lens, supposed to be in a fluid state.

Now press the flint-glass lens from the middle inward (permitting a corresponding part of the fluid crown-glass lens to pass into the open space resulting from such bending) so far that exactly one-half of the mass of the (supposed to be fluid) crown-glass lens has passed over to the other side of the flint-glass lens; then this latter would have the desired form corresponding to the least spherical aberration, as will be readily seen from figure 2.

The objective altered in this way, consisting of two positive crown-glass lenses of equal focal value and one double concave flint-glass lens, fulfils certainly in the highest degree, all the conditions of achromatism, for the over-correction at the margin as well as the under-correction of the centre are completely neutralized. But instead of this, the spherical aberration is at its maximum. In other words (presuming the outer surfaces to remain unaltered), every deviation of the flint-glass lens from this form, Fig. 2, would include a corresponding reduction of the spherical aberration (at the expense of achromatism).

The flint-glass lens of the double objective consequently can only entirely correct the chromatic aberration when it absolutely does nothing towards correcting the spherical aberration.

If we now suppose the crown-glass lens C, Fig. 3, while retaining the form of its surfaces, to be so much thickened, that without touching or cutting the surfaces, a concentric spherical cut (from the axis) can be made through it, in such a way that the outer one of the two parts resulting therefrom forms a negative (convex concave) lens (*c*, *c*, Fig. 3); we then have again in the other part resulting from the cut, a triple combined lens, which for itself, that is, if the negative crown-glass lens (*c*, *c*,) were entirely taken away, would, the source of light remaining the same, cause a very considerable spherical aberration at the newly cut surface. This aberration, or rather the sum of the aberrations of both of the outer surfaces of this triplet, may, however, without changing the

foci of the lens, be considerably reduced by bending the same back in the middle towards A, because by this curvature the lens is made to approach that form which corresponds to the minimum of spherical aberration, that is, in which the refraction at the surface of entrance is equal to that at the surface of exit.

If now, this deviation of the triple lens from the best form is so great (*i. e.*, the radius of the spherical cut just sufficiently short), so that the part of spherical aberration capable of being neutralized by the bending is equal to the spherical aberration of the combined objective, the neutralization of which is the object sought, then this bending back will be just sufficient to entirely free the objective from all spherical aberration. With regard to the aberrations of the higher order, however, it is better to choose for the cut a still shorter radius of curvature, and to carry the bending back only far enough to neutralize the aberration in question, during which, however, the bending of the flint-glass lens, to reobtain for the latter the above described best form, must be effected in a correspondingly lesser degree.

This operation, which completes the new objective, is represented in Fig. 4.

The space between the lenses *c*, *c*, and *b* (Fig. 4), resulting from this change of form, will then represent a meniscus, which, if consisting of the same material (crown glass), would have a very long focus, whose spherical aberration, however, would be equal to that of the objective out of which it is cut.

On closer examination of this mode of neutralizing the spherical aberration, it appears that the flint-glass lens of the double objective (Fig. 1) has, in comparison with it, a little the advantage, on account of its greater power of refraction, especially in regard to the aberrations of the higher order. But this inconsiderable advantage is abundantly outweighed by the circumstance, that with this new mode a very large margin is left for the choice of the radius of curvature of the cut, whereby, in fact, the advantage of a much higher correction of the spherical aberration may be obtained than would be possible in a double objective, even if the chromatic over-correction at the rim were entirely left out of consideration.

Considering the capacity of transmitting light of this quadruple objective, it must theoretically be admitted that the greater number of surfaces must cause a corresponding loss of light. By cement-

ing,[4] however, the lenses which join each other, this loss may be made for four surfaces infinitely small. At the other four surfaces, however, a somewhat smaller loss of light takes place than is the case at the four surfaces of the double objective when this is not cemented,[5] for flint glass surfaces cause a greater loss of light than crown-glass surfaces, and the four free surfaces of the quadruple objective are crown-glass surfaces. So the excess in loss of light of the quadruple over the double objective reduces itself, strictly speaking, to that part which is caused by the very unimportant difference in refraction between the crown glass and the medium used for cementing.

On the other hand practical experience teaches that if, by the increase of the number of lenses in any optical instrument, any advantage can be gained, even if such advantage is only a very slight one, the loss of light is of secondary importance, and need not be considered.[6]

At the close of this article, may it be permitted to me, the author thereof and inventor of the objective above described, to address personally a few words relative to my invention, to the representative men of science:

I have already calculated, and in connection with Messrs. Bausch & Lomb of this city, constructed an objective of 4½ inch clear aperture and fifty-two inch focal distance, of the above described new form.

(Previous thereto I had already constructed for the Centennial Exposition, a 4 inch objective, which however, after completing the second one of 4½ inch, and the important practical experiences gained in the construction of the latter, I consider as falling short of complete success.)

[4] By a new method I am enabled to cement even the largest lenses without difficulty.

[5] A double objective with surfaces not joining and consequently not cemented, is on account of better correction of the aberrations, to be preferred to a cemented one.

[6] How much have the strongly magnifying objectives of the microscope, naturally of such slight capacity of transmitting light, been improved by the increase of the number of lenses. At the time when it was thought that a stronger magnifying power than 500 times could never be applied to practical advantage on account of the want of light, the idea of constructing an objective of nine to ten lenses, with one twenty-fifth inch focus would probably have been laughed at; and yet the image produced by such an objective of modern construction, on account of the better correction of the aberrations, and the greater sharpness of definition resulting therefrom, gives the impression that more light is transmitted than by a one-fifth inch of the older construction.

In the face of such facts, every objection against the application of more than two lenses in the construction of Telescope-Objectives may be considered entirely refuted.

I believe I may conscientiously assert that this new objective will fully justify all expectations which my above description may have caused to be formed, not only equalling the performance of instruments of much larger dimensions, and of the best quality, but surpassing them in freedom from color and in clearness and sharpness of definition. The impression made by viewing a terrestrial object in a clear and quiet atmosphere, with this objective, is indeed a surprising one.

Animated by the desire to contribute by the construction of improved instruments a small share towards the progress of science, I shall always endeavor to conform to the wishes and desires of its representatives, and thankfully accept their kind counsels, advice and information, convinced that I shall succeed in meriting the assistance and approbation of the Scientific World, for my above described invention as well as for any other efforts in similar directions.

CONTRIBUTIONS TO THE PHYSICS OF THE GULF OF MEXICO, AND ITS CHIEF AFFLUENT, THE MISSISSIPPI RIVER. By C. G. FORSHEY, of New Orleans, La.

THE GULF OF MEXICO.—This huge reservoir of water, the Cis-Atlantic Mediterranean, lies conformably along the entire southern front of the United States of North America, presenting a vast semicircle 1000 miles from east to west, and 600 miles average width. And about midway of this curve, the Mississippi river enters it, bringing the waters of twenty-three states and larger territories. Its branches from the east and from the west spread out and have breadth of 1600 miles in longitude, reaching round, on both extremes, the shorter tributaries that contribute to the great basin of the Gulf.

BOUNDARY AND DIMENSIONS OF THE GULF.—The Gulf of Mexico has a length of 1000 miles when measured from the peninsula of Florida to Vera Cruz or Tampico. Its breadth at the neck made

by the Delta of the Mississippi and the Yucatan peninsula. South Pass Mouth to Cape Catoche, is 535 miles; and its greatest breadth, from Sabine Bay to Laguna de Terminos, in the Bay of Campeachy, is fully 800 miles.

Boundary.—Its most northerly extreme may be taken from Mississippi City to Santa Rosa Sound, at 30° 25′ north; its most easterly at Cape Sable to Cadenas in Cuba, at 81° 20′ west longitude; its most southerly point is at the mouth of the Coaxacualcos River, at 18° 5′ north latitude, and its most westerly extreme is at Altamira in Mexico, longitude 97° 40′ west. This gives 12° 20′ of latitude and 16° 20′ of longitude.

Area.—Its area, including its bays proper, is 600,000 square miles.

Depths.— The depth of the Gulf of Mexico, derived from all accessible sources, has a mean of 820 fathoms, or about 4920 feet.

A mean of 30 soundings at equal distances of 20 miles, from Havana to South Pass of the Mississippi River, gives 1144 fathoms depth. The distance is 600 miles. And from Key West to Havana, 102 miles, a mean of 10 soundings gives 536 fathoms, equal to 3216 feet. A line extending from Cape Romano to Dry Tortugas, S. 70° west, 110 miles, has nowhere more than 20 fathoms; and producing the line, it is more than 140 miles before we reach the 100 fathom depth. The shoals widen, northwestward to Cedar Keys, where they are 150 miles wide; and then contract to Appalachee Bay, where the 100 fathom line is 60 miles from shore. Most of the distance the depth is less than 20 fathoms.

Depths from shore inward.—To form a correct judgment of the nature and general slope of the basin, and its conformities to the watershed about it, we will draw radii to the curve of the Gulf shore, beginning at the Straits of Florida.

First, the line bounding the Gulf on the east from Cape Sable to the shores off Cardenas. The distance is about 120 miles; and the shoal water and the depth on the reefs, 23 miles out, are not more than 5 fathoms—generally from 1 to 2 fathoms. This line is taken due south. Thence proceeding up the coast, the line from Cape Romano S. 40 E., and measuring the depths at 10, 20, 40, 60, 80, 100, 120, 140, 160, and 180 miles, and at the 500 fathoms depth, we present the subjoined results, and construct the following table:—

TABLE OF SLOPES TAKEN ON LINES NORMAL TO THE CURVED BOUNDARY, AND RUNNING BENEATH THE SURFACE. THE CURVE (REPRESENTED BY THE DOTTED LINE) CUTS THE DELTAS.

Distance from Coast..	10	20	40	60	80	100	120	140	160	180	200	Miles.
To Cardenas.....	1 fath.	3	40	·250	430·	700	600					The shore of Cuba.
Key West to Havana..	31	·290	267	·815	710	240						
Parallel with Cuba. S. 45 W.....	80	.130	374	416·	512	900	1200					
Cape Romano, S. 65 W.	6	12	16	23	33	40	50	65·	183·	2080		
Rio Pinos Longos, S. 67 W.....	7.5	13	18	23	30	60	77	.113	103.	1720		
Bay Port, S. 65 W.....	4.5	10	13	18	22	32	85	.174	382.	1800		
Steinhatchee, S. 55 W.	6	10.5	15	18	25	32	60	.142	350.	763	1800	
Appalachee Bay, S. 55 W.....	0	0	10	23	50	100	.130	280.	1511	1800	1800	30 m. wide and 80 m. long; shore line indented by bays.
Santa Rosa, S. 25 W...	10	33	91	·206	207	300	426	·550	1500	1775	1700	
Mobile Bay, S. 10 W...	15	20	40	·175	.800	1050	1100	1250	1400	1400	1500	2000 f. at 340 m. from shore; thence gently to mid-depth.
Near West of Delta, S.	0*	0*	0*	0*	0*	6	55	.300	.560	690	1101	From Miss. Sound. Delta projects 100 m. nearly.
Caillou Bay, S.....	0†	0†	0†	†0	0†	5	12	41	100·	500·	608	Projection of Delta.
Tigre Pt., S. 10 E.....	2	5	10	15	18	60	84	·140	500	·600	800	
Sabine Pass, S. 20 E...	2	3	7.5	12	13	18	50	·200	240	500·	700	400 m.; thence gently to mid-depth.
Mouth of the Brasos Velasco. S. 40 E.....	10	15	18	20	100	·500	·805	900	1000	1200	1500	
Matagorda I., S. 46 E..	10	13	27	58	80	·200	300·	820	1000	1200	1500	
Padre I., S. 70 E.....	3	10	15	100	·500	·650	805	900	1000	1200	1500	Convergent.
Rio Grande, S. 85 E...	13	23	33	·185	·520	555	1600	1700	1800	1760	1760	About 650 m.; and thence 1800 to 2000 f. for a dist. of 700 m.
Distance from Coast..	10	20	40	60	80	100	120	140	160	180	200	

* On shore in alluvion. † Alluvion projects.

The above table shows an irregular sloping of the Gulf towards its central portions, after leaving the coral reefs, or cliffs, at 85° west longitude; and with such inclination that its central line of depth runs north 85° west, with a maximum of about 2000 fathoms.

From the Cuban shore out to sea, it deepens very rapidly, reaching 1000 fathoms in 50 or 60 miles; but towards the Florida straits, it shoals up to about 800 fathoms maximum depth and as above remarked, leaves but about 820 fathoms, the mean depth of the straits.[1]

Valley in the Depths of the Gulf.—The bottom of the Gulf of Mexico presents a very remarkable valley of nearly uniform depth. This plateau is about 150 miles in width, and 740 miles in length, from east to west; and thence to the south and west we have no soundings. It is probable that it extends 200 miles farther in the direction of the State of Vera Cruz, and the Bay of Campeachy.

From this valley there is an enormous projection of like depth towards Pensacola and Mobile bays.

This depression undoubtedly extends farther westward, perhaps to Sabine river; but is invaded by the contributions of the Mississippi river, and filled with the alluvial deposits brought down by that torrent. The lines drawn in the table will lend probability to the hypothesis.

It is the mission of the Mississippi river and smaller streams to fill the Gulf of Mexico. Already they have elevated above the water surface some 10,000 square miles of alluvion, measuring from the curve of the Gulf, as indicated by the uplands round Lake Pontchartrain, and the continuation of the same to the Vermilion and Calcasieu bays. It has spread out to the south and westward, on the bottom of the Gulf an area of alluvion, similar in character, quality, and perhaps vastly greater extent. The soundings and the kind of bottom indicate it. The prevailing winds, during the season of high water, are from east and southeast; and the current of the river is southward and southwestward. The shore limits the flow westward of the mouths, and

[1] It is instructive and interesting to notice the extensive flat that projects for 400 miles of the circuit from Cape Romano to Appalachee Bay, and beyond. This is again projected in front of the West Louisiana, and East Texas Coasts, for a distance of 300 miles of the shore line. A curve line, traced in the table, shows the ordinates of measurement for these flats.

the current takes its only course and flows southwestward. The Gulf has filled, and will fill in that direction in future time, because the fresh water floats on the surface, and gradually drops the sediment it contributes into the depths of the Gulf.

This enormous valley, from 2 to 2.25 miles in depth, is so capacious that, supposing the Mississippi river to have eroded its valley from half a mile of average elevation, from the heights of the Alleghanies, and cast the contents into the submerged valley at the foot, it would scarce show more than is now manifest from its present topography. And as a careful computation of the elevation of the Mississippi valley, at the present epoch in its geological history, shows it to be 1318 feet of mean height, above the level of the sea; if all its valley were to be denuded down to tide-level, over its 1,317,000 square miles, carried forward and spread over the bottom of the Gulf, it would still leave the Gulf one-half its present capacity, or 2186 feet in depth. Such is the vastness of this great submerged valley,—such its profound abyss.

A Geological Suggestion.—The depths are very irregular, and vary from 0 at the shore, to 12,150 feet, = 2.26 miles. In some places west of the Florida coast, some 100 miles distant, the basin slope becomes very precipitous, there being a jagged or very broken cliff, for 150 or more miles. The coral reefs are supposed to prevail, and present the form of this cliff. They are probably based upon the super-tertiary or tertiary bluffs, which make the 100 miles of plateau, thence to and upon the shores of Florida and Alabama.

Contents.—The cubic contents of the Gulf are computed at 85,040,271,360,000,000,[2] or 85 quadrillions of cubic feet; more than 3.15 quadrillions cubic yards. This gives but a vague idea of quantity, and will be illustrated by measuring its contents in yearly contributions of its chief tributary.

The Drainage of the Mississippi.—This affluent pours in annually a measured quantity of 21.3 trillions of cubic feet. This quantity, divided into the contents of the basin, shows that it would require 4000 years to fill it from the Mississippi alone.

[2] *Assuming the depths* at 820 fathoms, or 4920 feet average, we are enabled to compute the contents, and treat of its movements. The area of the Gulf amounts to 600,000 square miles; nearly equal to one-half of the valley of the Mississippi River, and of a depth as above

General Drainage into Gulf.—For convenience of geographic comparison, of the different valleys, I submit the following table:[3]—

Upper Mississippi Valley	169,000
Missouri Valley	518,000
Ohio Valley	214,000
St. Francis Valley	10,500
Arkansas Valley	189,000
Red River Valley	93,100

EAST OF THE MISSISSIPPI.

Withlacoochee, Sewanee and Appalachicola	49,200
Choctawhatchee and Escambia	16,800
Mobile (Alabama and Tombigbee)	38,120
Pascagoula, Wolf River and Biloxi	10,200
Pearl River	10,180
Chefuncta, Tangiapaho and Amite	4,800

WEST OF THE MISSISSIPPI IN U. S.

Sabine and Neches	20,000
Trinity and San Jacinto	25,300
Brasos and San Bernardo	36,770
Colorado and Lavacca	19,440
San Antonio and Guadalupe	17,650
Nueces	23,510
Petronelles, San Fernando and Gertrudes	10,130
Rio Grande	257,900

The drainage into the Gulf of Mexico, recomputed, produces the subjoined result:

The Valley of the Mississippi	1,317,700
The Water Shed, east	123,200
The Water Shed, west to Rio Grande	152,830
The Rio Grande Valley	257,900
Mexico, Guatemala and Yucatan	310,200
	2,161,830 Sq. m.

[3] Some of these areas are taken as found from Humphrey and Abbott's "Physics and Hydraulics of the Mississippi River;" but much of their work has been recomputed,—all indeed; but changes that are unimportant are not made. The area of the whole valley of the Mississippi river has been changed, because the surveys of the last sixteen years have been added, and corrections made that are material. I have included the Red river in the Mississippi Valley, because I saw no reason for excluding it, that would not apply to any other river.

The drainage into the Gulf comes from 2,161,830 square miles, or 843,000 square miles in addition to the valley of the Mississippi. Of this amount 123,200 square miles are from east of the Mississippi, and drain fifty per cent. of its rainfall of 54 inches, which adds 9.6 trillions cubic feet to the basin. Of the remaining (843,000—123,200–) 720,000 square miles, there lies east of the "Dry Line," of longitude 97° west, in Louisiana and Texas, about 57,000 square miles that pertains to the humid region, and receives upon it fully 42 inches of rain; and, moreover, discharges nearly half of its humidity back into the Gulf. We may, therefore, compute it at 20 inches, or a total of 2.173 trillions cubic feet of water discharged into the Gulf annually.

But there still remains an area of 663,000 square miles, embracing the two dry lands of the Rio Grande valley, the upper Brasos, Colorado and Nuéces; and the entire area of Mexico and Guatemala, embraced in the watershed. Most of this region approximates to desert, and drains but little of its water into the Gulf. We have observations from only ten stations in this area and these are nearly all in the valley of the Rio Grande and upper Colorado. These give a mean of 17.3 inches for the rainfall. It is a large average; but in the absence of other information we will adopt these figures. And as all the watershed not embraced in the Rio Grande valley has but short distances for the flow of the waters discharged, we will suppose that half the water which falls reaches the Gulf. But the valley of the Rio Grande has an area of 257,900 square miles, and has a long distance through desert country, of great heat and barrenness, to travel; and the upper Brasos, Colorado and Nuéces, have like aridity, with about 96,000 square miles. We will estimate their discharge at about 10 per cent. of the whole rainfall,—assumed at 18 inches; or that 1.8 inches reaches the Gulf. This when computed amounts to 1.5, or one and a half trillions of cubic feet; while, of that discharged on Mexico, alike small in quantity, or only 18 inches, one-fourth is drained into the Gulf, or 4.5 inches. This area is 310,000 square miles; its drainage amounts to 6.3 trillions of cubic feet. We have then the drainage of the entire watershed, which, in tabular form, stands thus:

DRAINAGE INTO THE GULF.	BASIN AREA AND DISCHARGE.		YEARLY RAIN.	RATIO	DISCH'GE.
	Sq. Miles.	Quant. Bills.	Inch.		Mean per Sec.
Drainage of Mississippi Valley	1317.690	21.300	30.4	0.25	675.000
Drainage East of Mississippi Valley	123.200	9.640	54	0.50	305.000
Drainage West of Mississippi Valley to lon. 97°.	57.000	2.173	42	0.50	70.000
Drainage of West Texas and Rio Grande	{ 97.000 / 257.000	1.491	18	0.10	35.000
Drainage of Mexico and Guatemala	310.000	3.176	18	0.25	200.000
Drainage of the whole Gulf	2.161.890	37.780.000.000 cubic feet.			

The drainage of the watershed into the Gulf amounts to 37.78 trillions of cubic feet; while the Gulf contents amount to 85 quadrillions of cubic feet. It then would require a period to fill the Gulf from its watershed alone, equal to 2,250 years!—and if all the water which falls upon the watershed were returned to the Gulf, it would fill it again in a space of almost 900 years!!

Inlet of the Gulf.—The Gulf of Mexico receives into its basin only about $\frac{1}{22\frac{1}{50}}$ of its contents, annually, from the rivers which discharge their waters into the reservoir.

But it receives a current from the Caribbean Sea 105 miles wide —554,400 feet; and 560 fathoms, or 3360 feet mean depth, and running at the surface rate, about 1.8 miles per hour. This current enters on the southeast side of the Gulf, east of midway, having Cape San Antonio, off the west side of the Isle of Cuba, on the east; and Contoy Island off the coast of Campeachy, on its west side. These two then—the drainage of its watershed, and the Straits of Yucatan—are its sources of supply.

Outlet of the Gulf.—The two drafts upon the basin are the Gulf-stream outlet through the Straits of Florida, and the evaporation that supplies the watershed of the Gulf, and all of the northern, and part of the eastern portion of North America.

This portion of the Gulf which borders the Florida straits continues to contract until far beyond the limit assigned the Gulf. It divides in twain, and the Nicholas channel goes off around Nassau, and the Great Bahamas, to the south and east: and it

bears off its share of the waters of the Gulf. The process of warming which the waters have experienced in the Gulf and Caribbean, starts the flow with 2.5 miles current along the Atlantic shore; and the waters around the Bahamas, though not sounded, must account for the want of balance shown between the *inlet* and *outlet* of the Basin. The contraction continues until the Gulf-stream has turned the eastern slope of the Florida Reefs, and until the measured width is only 47 miles; say from Cape Florida to Gun-Cay Light.

At this narrowest neck, the soundings give a cross-section of only 300 fathoms, = 1800 feet depth; and the current a velocity of two and a half miles per hour. This would be the true adjutage, but for the partition the stream experiences, at the Nicholas Channel.

THE PHYSICS OF THE WATERS OF THE GULF. — It is interesting to the physicist to observe the nearness to a balance in the cross-sections of inlet and outlet, and the probable method of accounting for the difference.

If the whole depth should be occupied in filling it, across the Campeachy Straits at the rate observed, it would require about 203 days, with the surface velocity, to complete the filling; and the discharge through the Straits of Florida would, in like manner, occupy 214 days in discharging the Basin.

The difference of 8 days delivery would have to be imputed to evaporation.

Evaporation can only be approximated by the fall of rain; and that by the measured discharge into the Gulf, through the rivers.

The Delta Survey estimates the annual return by the Mississippi River, at 19.5 trillions of cubic feet. I have estimated the other rivers as adding one-half more to this amount, and hence name 32,950 billions, as the amount of cubic feet returned to the Gulf.

The same authority estimates the rainfall at 41.2 inches per year; and a mean of all the stations of the Signal Office for 1874 gives 40.3 inches. We may adopt the Delta Survey, as a very near approximation. The total drainage into the Gulf we have computed at 37,780 billions of cubic feet.

But the area, watered by the Gulf, we suppose to be considerably larger than the watershed of the Gulf of Mexico. Perhaps one-fourth added to the amount we have thus accounted for, and the amount assumed will reach 50 trillions of cubic feet.

Now taking the estimate of Humphreys and Abbott, that one-fourth the rainfall is returned on the surface, and accounted for;

then we have the round amount of 200 trillions of cubic feet for the evaporation from the Gulf.

This estimate will be but about $\frac{1}{4}\frac{1}{8}$ part of the contents of the Basin, whereas the Campeachy inlet exceeds the outlet by $\frac{1}{2}\frac{1}{5}$ of its contents.

Such is calculation, based upon the best measurements we have.

Cold Currents. — Let us now make some estimates only upon plausible reasoning of the probable currents, due to temperatures at great depths.

We have the authority of Wyville Thompson, in his ever to be remembered deep sea explorations on board the Challenger, for placing all the temperatures of 500 + fathoms, at from 40° to 33° of Fahrenheit. We have no deep sea temperatures from the Gulf but the summer and surface temperatures. At Key West, for example, these are about 83° to 85°, and 86° is the maximum temperature of the Gulf-stream.

From the velocity of the currents observed upon the surface, and which I have taken from actual observations, it is highly probable that the movement is confined to the upper portions of this volume, and that the lower depths are either undisturbed, or only *secularly* changed.

Recognizing the high temperatures of the tropics, from which the Campeachy Straits derives her waters; and also recognizing the trade winds as heaping up the waters on the western shore,— the exit through the Florida Straits *is a necessity*. The circulation observed is amply accounted for.

Supposing these currents to descend to only half the waters in the inlet and outlet; and which is highly probable, the wind's influence at the surface, to give to the velocity an abnormal rate, which does not descend far into the depths, and we shall have to divide by four, the observed rate, and multiply the cross-section by .45 instead of 1.8 miles per hour. And our accumulation of excess in the inlet over the outlet of the Gulf will be reduced to $\frac{1}{1}\frac{1}{0}\frac{1}{0}$ or one per cent. yearly, of the whole Gulf.

This would appear a huge amount of water, when contemplated in one vast volume; but when we reflect upon the duty the stupendous system of irrigation has to perform, the watering of a whole continent, the fertilizing and clothing with foliage, and blossom and grain, such as the earth elsewhere never saw, we shall cease to wonder at the quantity, and only remain impressed with the grandeur and beneficence of nature's processes.

Here, indeed, "There went up a mist," from the sea, "and watered all the earth."

Process of Reclamation.— The alluvial invasion of the Gulf, the footsteps of the Mississippi as it encroaches upon the northern border of the basin, is obvious on the map to the eye of all, and especially to those who reflect upon cause and effect, and inspect the map of the country. The amounts and rate contributed by this largest affluent are measured approximately, and shown by the Delta Survey of Humphreys and Abbot. The distribution of the amounts contributed by the various streams, beneath the waters of the Gulf, is determined by the soundings of the Coast Survey. These results are before me.

Precipitation and Drift Matter.—The alluvial matter carried forward in solution, and precipitated upon the bottom, by careful measurement continued two years, daily, in all portions of the river and at all depths, amounts to a solid block of one mile square, and 241 feet high.

If the amount drifted forward on the bottom of the river ascertained just as persistently for the two years' observations to be enormous in bulk, but immeasurable in quantity, be estimated, as I have assumed, at three times the amount in suspension, then the whole quantity contributed by the river to the Gulf would raise the column 723 feet.

As the Gulf area has been computed at 600.000 square miles, and its average depth at 820 fathoms or 4920 feet, it will require the whole Mississippi's contributions, a period of seven years to build one column to the surface; and to fill the Gulf with sedimentary matter a period of 4.200,000 years.

The process of reclamation then is the addition to the emerged land of the coast, a share of this matter yearly as the centuries progress, by precipitation in part and by drift matter in part, which, on its delivery to the Gulf winds, waves and tides, is distributed along the shores and over the bottom in consecutive lamina or strata.

Former Boundary of the Gulf. — Independent of theory, it is obvious that the Lake Pontchartrain, Barataria, Atchafalaya, Cote Blanche and Vermilion Bays, were recently portions of the Gulf of Mexico; and that these are now being filled by the river deposits and reclaimed from the sea, just as the areas between them have been filled.

The boundary of the recent Gulf must be traced around them to appreciate the footsteps of this invasion. The line to be symmetri-

cal and restore the olden curve of the Gulf as indicated along the Mississippi Sound, east of the Delta, and along the Calcasieu Coast west of the Delta, would embrace 7600 square miles of land and marsh, nearly all now above water. The upland, manifestly not alluvion, lies immediately north of this line and warrants the hypothesis.

The ten fathom line as sounded in the Gulf, connected from off Ship Island to the west and front of Vermilion Bay, would pass through New Orleans, at lat. 30° north. Now it sweeps down around the mouths of the Mississippi River, below lat. 28° 50′, and returns some 20 miles in front of the Barataria Bay; then it takes another sweep southward, in front of the Timbalier and Caillou Bays, reaching near half a degree farther south than in its river sweep, and returns again west of the Vermilion Bay, near the Calcasieu. Again it sweeps southward in front of the Sabine River, and returns on the west of Galveston Bay. Its first curve south is near 50 miles at sea, and the next, that in front of Sabine, is more than 70 miles from shore. As we shall see, the broad plateau, spread out in this last extension, is continued under water an indefinite distance, some 150 miles, before we are warranted in giving a limit to the alluvion.

In fact, the prevailing winds of spring and summer, when the floods of the Mississippi River are prevailing, are from the southeast, and drive the waters which are lightest and lie upon the surface, from the Atchafalaya and the river proper for a long distance, even 40 or 50 miles in this direction.

The limit of the alluvion may be inferred from the samples of bottom dredged up in the Coast Survey. The white and yellow sand are contributions from the drift-beds, and the orange sand of Mississippi and Alabama, which have their outcrop in front and east of the Mississippi Sound. These near shore have not suffered submersion from the river's contributions. Farther out from shore they mingle somewhat until they are both lost in the depths of the Gulf. On the west they are nowhere so clearly of an original formation. The alluvion seems to prevail all the way to the front of Galveston Bay.[4]

[4] The enormous projection of alluvion in front of Caillou Bay and Last Island shows that the river's mouth discharged there for thousands of years before it adopted the present mouths and channels. Indeed its present débouchure, moved a little westward, will have to continue many thousands of years to bring up the Barataria region and the Delta submerged, to the general curve shown in the ten fathom soundings west of Vermilion Bay.

CURRENTS IN THE GULF.—So vast a body of water would require some enormous motive power to stir the whole volume. Nothing short of gravitation, or the heating power of a tropical belt, could move it. Gravitation would long since have restored the equilibrium and put the waters at rest, had the tilted basin in some remote period disturbed its level. To the thermal influences alone, then, can we impute any movement that may disturb so vast a volume. In fact the body of the waters is not disturbed, except in secular manner in obedience to the law of distribution of heat in a fluid that is inexpansible.

The inlet and the outlet of the Gulf, the Yucatan and Florida Straits, are both on the same, southeast, side of the basin, and not more than 300 miles apart. The current, if established, would hug the coast of Cuba, taking the shortest route between the two apertures, thus leaving undisturbed the main body of the basin. No current is known to mariners or to science that would account for the Gulf Stream. A short distance only from the two openings, perhaps 50 or 60 miles, is the influence felt.

Such is the result of theory based upon approximate research and experiment of both Army and Coast Survey, for forty years.[5] There is no stream in the Gulf.

[5] The researches for these and other purposes, instituted by the U. S. Government, have been numerous and elaborate:

In the year 1838, Capt. Talcott of the Topographical Engineers, made a thorough and elaborate survey about the mouths and passes of the Mississippi River. His assistant Geo. R. Meade, since Gen. Meade, reports that for seven miles out from the bar at the Southwest Pass, careful observations were made "under all circumstances of wind and tide, and such currents," meaning a littoral current, "were never found."

Subjoined is a table of Maury's Track-charts of 100 voyages in the Gulf, embracing all the observations within 80 miles of the mouths of the Mississippi, showing the location of all the currents experienced in these voyages. This table seems to prove the absence of any permanent current.

The recent allegation of a "littoral current" off the mouths of the Mississippi, and near enough to affect the deposits near the works there, has caused a careful collation of evidence.

Four different operations of the Coast Survey, 1852, 1862, 1873, and 1877, are in evidence. Capt. Patterson, Supt., says, in a note to me of Feb., 1874, that "no such current has been found," meaning a littoral current. Though the search has not been special for that object.

It will be remarked that these observations extend from shore outward, 100, 200, 300 miles, and from Key West to the Rio Grande.

The Delta Survey of the U. S. Engineers in 1851 to 1854, made a careful survey about the mouths and bars of the river (per Prof. Forshey, Assistant Civil Engineer), in addition to those made by Ellet in 1851, on the Commission for the Delta Survey. No littoral current was found.

Col. Stephen Long, U. S. Engineer, made surveys for the works of Craig & Rightor in 1856–7. He found no littoral current.

Again, in 1859–60, the Delta Survey was resumed, and per Mr. George F. Fuller, Civil Assistant, made elaborate surveys for currents upon the bars and beyond in deep water, with like result, so far as to find that the shore was not eroded by a littoral current.

TABLE SHOWING THE DIRECTION AND RATE OF CURRENTS ABOUT THE MOUTHS OF THE MISSISSIPPI.—*Constructed from* MAURY.

NO.	LOCALITY.	COURSE.	MILES. PER HR.	REMARKS.
1	70 miles S. E. of Chandeleurs....	N. N. W.	.8	
2	30 miles E. of Pass a l'Outre.....	N. E.	1.5	
3	40 miles S. E. of South Pass.....	S.	1.0	
4	65 miles S. E. of South Pass.....	S.	1.2	All but one within 80 miles of mouth. Curve described from South Pass.
5	40 miles E. S. E. of South Pass...	N. E.	1.0	
6	12 miles S. W. of S. W. Pass. ...	W. N. W.	.5	
7	78 miles E. of Pass a l'Outre.....	S. E.	.5	
8	60 miles E. of Pass a l'Outre.....	S. S. E.	.6	
9	65 miles S. E. of South Pass.....	S.	.8	
10	58 miles W. S. W. of S. W. Pass.	W.	.5	
11	120 miles S. S. W. of S. W. Pass...	N. N. W.	.7	

Major Howell, U. S. Engineer in charge of the Gulf improvements, has made a series of surveys in 1873-4-5-6-7, for the purpose, among other things, of ascertaining what currents play about the bars at the mouths of the river. His experiments, made chiefly through H. C. Collins, Civil Assistant, demonstrate the absence of any permanent current on or about the bars of the river and for 14 miles out into 300 feet depth of water.

The commission of Engineers, on Canal and Jettees, of November, 1874, may be quoted as reporting against the allegation of a littoral current, as it is neither alleged or denied, in their report in favor of the Jettee experiment.

In conclusion we quote the language of J. E. Hilgard, long an assistant in the Coast Survey on the Gulf of Mexico, and still in charge of the charts and soundings of the office. He verbally informed the writer that "no currents other than the transitory mutable wind and tidal currents, were known to the Coast Survey; out of the immediate vicinity of the Yucatan and the Florida Straits."

PHYSICS OF THE LOWER MISSISSIPPI RIVER. By C. G. FORSHEY, of New Orleans, La.

PREFACE.—Having considered the Gulf of Mexico toward which all the Geological beds of the Mississippi valley incline, we but follow the natural order in tracing the drainage, and flow of the waters, which find their rest in their original source from which they were borne.

The Great River which concentrates these waters enters the basin on the north side, and has made a considerable indentation about its débouchure. We propose to examine it in this invasion of the Gulf.

THE BARS AND MOUTHS OF THE MISSISSIPPI.—The great development of population and industry, and the consequent commerce of the valley of the Mississippi River, have created a demand for the deep and permanent navigation of his channels out to the ocean and to the marts of the world. This cannot be longer delayed without great embarrassment and serious loss to productive industry.

Everything that contributes to the solution of this demand is well worthy the consideration of the Academies of Science and learned bodies of the American public. It is proposed, in this paper, to discuss the Physics of the Passes and Mouths, according to the best lights that science and investigation can afford.

MEASUREMENTS.—The river flows for the last 300 miles of its course between banks and levees that are, by a mean of two hundred measurements, 2,735 feet apart.

The average mean depth of the central channel is 121 feet at high-water; and the mean cross-section of the body of the river is 200,000 square feet.

The fall of the surface plane measured from high water is 49.5 feet, which gives a plane of 2.28 inches per mile of channel. This is from the mouth of Red River, the last tributary to the mouth of the Mississippi.

The mean velocity of the surface current in mid-channel is about 6 feet per second or 4 miles per hour; and the mean annual velocity of the entire river volume is 3.8 feet per second or 2.23 miles per hour.

The average discharge of the whole volume is 610,000 cubic feet per second; and the total volume carried into the Gulf by the river

amounts to 21,300,000,000,000 cubic feet: say twenty-one and three-tenths trillions of cubic feet of water in each year.[6]

AMOUNT AND QUALITY OF SEDIMENTARY MATTER.—The waters of the Mississippi River are always turbid, and bear to the Gulf in suspended form $\frac{1}{2900}$ or .00035 per cent. of its whole bulk, or $\frac{1}{1800}$ or .00055 per cent. of its whole weight of sedimentary matter.

This earthy matter proves, upon the examination of some thousands of samples, taken daily at all depths, and every portion of the river, for two years, to be composed of very fine sand, and highly comminuted aluminous matter, entirely free from organic substances.

These amounts are extremely small when compared to the water bearing them, and the amount of matter annually contributed to the Gulf, and observations in great numbers were made, to determine how these contributions should be accounted for.

It was ascertained early, say within the first month of observation, that there was some other undiscovered method of explaining the amount thrown out on the sand bars, in the crevasses of the levees and banks, and carried to the bars of the river at its mouths.

A single experiment made by the writer of these pages brought to light the secret.

The matter was borne along the bottom of the river, too heavy to be held in suspension. By far the greater amount passed off thus invisible. The amount could not be measured. The experiments were continued. Samples were taken during the whole of two years, and the drift matter never was found absent beneath a running current. From the greatest depth on the line of observation, and from the gently sloping shore of the bar on the other side, the parcels were taken.

After much reflection and desire to make the estimate reliable, I have concluded to estimate the amount of drift matter rolled or pushed along the bottom of the river, at three-fourths of the whole quantity by weight. Then if the sediment held in suspension is $\frac{1}{1800}$ of the whole river, the drift matter weighs $\frac{1}{600}$ of the river. By bulk these quantities are $\frac{1}{3000}$ and $\frac{1}{1000}$. Its composition was found to be: 1st, coarse silicious sand: 2nd, mud in balls and

[6] These data are taken mainly from the Delta Survey of Abbott and Humphreys. The writer of this paper conducted the Hydrometric operations of that survey, and feels at liberty to use it freely, with this mere statement, without always quoting or acknowledgment.

lumps, embracing sticks and leaves, from the size of half an inch in diameter, to two inches and even three inches in dimension; 3d, water-logged sticks, pieces of wood and roots.

These constitute the drift matter of the Mississippi River.

THE PASSES OF THE MISSISSIPPI.—At a distance of 18 miles from the Gulf, measured along the main channel of commerce, the river divides into three passes.

The first, called the Southwest Pass, bears off with a divergence of 50° from the main direction of the river, and has a direction of S. 25° W.

The cross-section of the Southwest Pass is 60,267 square feet; its discharge at flood season is 315,028 cubic feet per second. Its average width in symmetrical section is 1400 feet. Its length to the bar, 3 miles at sea from the land's margin, is 18 miles, measured from the divergence at the head of the passes; and its descent from that level is 2.9 feet or 1.8 inches per mile.

The second division is called the South Pass, and is a prolongation of the main channel in its general bearing. Its course is S. 25° E. Its cross-section, April 22, 1876, was 22,760 feet at high water, and its discharge 82,027 cubic feet per second. Its length to the bar, at about 2 miles at sea, is 13.5 miles. The average width of the Pass is 700 feet, and its fall, like all the passes, is 2.9 feet at high water, giving a slope to its plane of 2.44 inches per mile.

The third subdivision of the river is called the Northeast Pass, now more commonly the Pass a l'Outre,—bearing N. 78° E., taking the Pass a l'Outre as its continuation.

Its cross-section is 66,360 square feet at high water, and its discharge 309,700 cubic feet per second. Its length to the bar of Pass a l'Outre is about 15.5 miles; its plane of descent 2.9 feet at 2 inches per mile.

MEASUREMENTS OF THE RIVER AND PASSES.[7]

DATE.	Length. Miles.	Width. Mean, feet	Depth. Feet.	Fall, in. per m.	Section. Square ft.	Discharge. Cubic feet per sec.	PASS.	AUTHORITY.
Oct. 24, 1875.	25	2,640	59.8	1.40	157,277	274,722	Whole River above Jump.	Howell—Collins
Oct. 24, 1875.	23	.....	....	1.40	154,631	.....	Whole River below Jump.	Howell—Collins
Oct. 24, 1875.	20	.....	....	1.38	112,485	.....	Whole River below Cubitt's Gap.	Howell—Collins
April 23, 1875.	15.5	1,444	44.4	1.37	66,360	309,700	North-east Pass, 1 mile down.	Howell—Collins
May 19, 1877.	....	.....	....	....	66,995	293,000	North-east Pass, 1 mile down.	Howell—Collins
Oct. 26, 1850.	8.2	1,447	35.0	1.20	35,250	.....	.....	Prof. Forshey.
April 23, 1875.	18	1,245	46.2	1.88	60,267	315,028	South-west Pass, 1 mile down.	Howell—Collins
May 19, 1877.	....	.....	....	...	57,390	276,670	South-west Pass, 1 mile down.	Howell—Collins
April 22, 1875.	13.2	827	24.5	2.61	21,218	82,027	South Pass, 1 mile down.	Howell—Collins
May 19, 1877.	13.2	827	....	....	19,350	69,000	South Pass, 1 mile down.	Capt. Brown.
July 2, 1876.	13.2	827	26.4	2.61	23,560	.....	South Pass, 1 mile down.	Maj. Comstock.
Oct. 30, 1875.	12*	600	31	3.3	18,621	25,517	Pass Forshey (Jump).	Howell—Collins
Nov. 8, 1850.	5*	1,250	32	9.2	45,000	.....	Pass Forshey (Jump).	Prof. Forshey.
Aug. —, 1877.	7.	3,000	....	5.0	.....	.....	Cubitt's Gap.	Lieut. Maunday.
Oct. 20, 1875.	7.5*	4,000	5	5.0	18,621	25,517	Pass Howell (Cubitt's Gap).	Howell—Collins

WORKS FOR THE IMPROVEMENT OF THE PASSES IN NAVIGABLE DEPTH OF WATER: DREDGING.—The magnitude of the river and the peculiar nature of its passes and bars have been deemed

[7] This table discloses the effects of the operations now going on at the passes. The contraction of the outlets of all the several passes, by the sinking of mattresses in them, and the jettying of the South Pass to about 600 feet of width, and the closure of Grand Bayou.—all of which has been done within the year past (July, 1877) have driven out at the Jump, and at Cubitt's Gap, and over the banks and through the small bayous, an unmeasured, but large amount of water, estimated at 68,076 cubic feet, more

in the eye of mariners and navigators as presenting too formidable a task for treatment by any works that man could devise. The semi-dissolved nature of its continually forming banks and bars, the shifting of these from place to place, the upheaving "mud-lumps" from an unknown depth — these and the arrival annually of many thousands of cubic yards of sedimentary matter,— have forbidden any attempts to found work upon these shores.

Then there was the example of the mother country in having had under her care the mouths of the Ganges, the only similar stream under enlightened management. She had abstained from making any works to protect or deepen the channels of that river.

In 1838 the first survey was made by our government, and resulted in nothing more than the recommendation to dredge the channels. This has been done in various ways since that time. The three main experiments of dredging were, 1st, those of the Tow-boat Company, in which 18 feet water were kept for one year, 1853, for 75,000 dollars; 2nd, the dredging by Craig and Rightor, in 1856–7, and in which something like the same depth was accomplished; and 3d, the process now in operation by the U. S. Engineers, which has been continued between 8 and 9 years, with an additional foot of depth, from more powerful machinery.

than their duty. This is inferred from a comparison of the discharges of April, 1876, and May, 1877. Also compare the regular diminution of the cross-section of the South Pass, measured at a mile down.

It must be remarked that the South Pass is divided on its way down at about one-third the distance, and sends off through Grand Bayon one-third of its water to the westward into East Bay; and that the Northeast Pass sends off the Pass a l'Outre at 5½ miles in the direction it had, while the Northeast pass turned E. S. E., and at 10 miles it sends off the Southeast Pass, and then again turns due northeast, reaching the Gulf at 16.5 miles from the head of the passes.

The Southeast Pass has been closed for 30 years or more, and can be entered only by two bayous, the Selim Bayou and Buttermilk Chute, which connect across parallel with each other from the Northeast to the Southeast Pass. The Balize Bayou leaves the Northeast Pass at 2 miles above the head of the Southeast Pass. This Bayou was for more than a century, up to about 1845, the main pass for commerce, with from 15 to 18 feet of water on its bar. In 1850 the town of Balize, of 300 souls, built by the Pilots, was being removed to the Southwest Pass, that Pass having enlarged while the Balize was in decadence. The Southwest Pass and Pass a l'Outre have been the track of commerce for about 40 years, from the River to the Gulf, and reciprocally the latter having had for that time from 10 to 13 feet variable channel, and the Southwest Pass, nearly the whole time, about 15 feet at mid-tide as the normal depth.

* Capt. M. R. Brown, U. S. Engineers, placed in charge of the progress of the Jettee experiments of Capt. Eads: July 28, 1877, reports that there is a channel 20 feet deep and 145 feet wide. The 22 feet channel lacks 1270 feet of being out of the extreme of the Jettee.

The Jettee contract requires 20 feet deep and 200 feet wide, for the first payment of $500,000, and for the second a channel 22 feet deep, and 200 feet wide, through from River to Sea,

Limits of Dredging. — The Pass a l'Outre had a normal depth of about 15 feet at mean tide: and the dredges of the U. S., the McAlester and the Essayons, have increased that depth to about 16.5 feet. This has been for two years, up to August, 1875. Vessels of even 20 feet draft have passed, frequently, as the effect of dredging upon the bottom. The paddles of the boats have reached even below that depth; leaving the mud loose and practicable to the keels of vessels, so that they have passed, without stopping, through two feet more than the soundings.[8]

On passing to the Southwest Pass bar, they experienced a like effect, after the dredging had got fairly to work. Upon soundings of 17.5 feet to 19 feet, vessels with a draft of 20 feet, and in one instance of 21.5 feet, have passed the bar without detention. But for 25 years, since the introduction of dredging, this has been the limit. The buckets or paddles of the dredges have uniformly stirred the mud two, three, and four feet deeper than the vessels could pass. The mud closes over the channel again at this limit, which I placed at 19.5 feet at the great average.

The uniformity of this maximum result in the two passes is sufficiently remarkable to call for an explanation. Why is it that the dredging should be limited in its result, when dredging elsewhere knows no limit of depth?

[8] On the 13-14 April, 1876, a remarkable disturbance took place in the Pass a l'Outre, that compelled the dredge boats to leave that channel and repair to the Southwest Pass; and since that time they have worked upon that pass solely; the Pass a l'Outre having shoaled up to 9 or 10 feet.

In a single night the whole area was changed; a mud-lump (or other movement) having heaved up from a depth of 7 or 8 feet water, and thrown itself obliquely across the channel, raising its head 9 feet above the water in places, and covering an area of 17 acres that was formerly submerged. The movement, with various degrees of elevation, sometimes of depression, continued during the summer as a "glacial" or movement forward, and exhibited itself in the form of wrinkles or plications, and extended itself to all the vicinity of the passes, reaching to more than one thousand acres.

The dredgers found it impossible to keep down the upheaval across the channel; and the were withdrawn in August. It was definitely ascertained that the movement was continuous. The clearing away the upheaval of one day was no guaranty that to-morrow it would not be repeated and more than replaced.

The movement was normal or radial to the curve of the bar at sea. It was corrugated and in ridges; the seams and cracks being mainly parallel with the curve of deposit about the bar.

The glacial movement suggested by Major Howell, of the U. S. Engineers, in charge of the works, appears plausible and consistent with the facts, as they appear to me.

A demonstration of subsidence comes to light at the Jump. The telegraph cable was placed there on the surface in 1853, crossing the channel of the Jump. It was recently dug up by Mr. H.C. Collins, Assistant Engineer, at a depth of four feet; showing a subsidence of two inches per year. Other places show a consistency with this; but they are not so exactly measured.

Analysis of Material.— The inquiry may find a solution by referring to the surrounding alluvion.

It has a uniformity of level, that can only be accounted for by the law of gravitation. All the alluvion comes to a level in the vicinity of the months of the river, for the same reason that mortar, mush, tar or dough, sinks slowly to the same level.

Impervious. — The banks of the river, say 20 miles up from the months, are composed of alluvium, which has had the water extruded from it by long time, but such is its tenacity that the water cannot be rapidly compressed from it by its own weight. At a distance of 50 miles up, where the land is elevated, say 12 feet above the sea-level, we find the earth so impervious to water that it cannot be penetrated by it. The water that it still holds is incapable of travelling except by the channels, or orifices, that have been preserved from times of greater thinness, or gradually worn through the alluvium. The river rises each year to and above the level of the banks, but often does not affect the springs and wells that are close to its banks. This is from the impervious character of the material, after being compacted.

Semi-fluid. — The nearer the sea, however, the less completely have the waters been extruded, until the sea-level is reached; and here its material is still in a partially fluid condition; and like dough, or mortar, it acquires a level which it maintains unless disturbed by some extraneous force.

This is true for a distance of several miles along the shores and interior. Occasional mud-lumps disturb the level, and raise the surface ten or fifteen feet; and out of the reach of the sea-waves which usually level them. But so soon as the cause of elevation ceases (hydrostatic pressure from suppressed springs) the lumps sink down to the common level, by their own gravity. No trace is found of the thousand mud lumps that swarm around the bars of the various passes, though many of their springs are found upon the margin of the salt water. They disappear just as a shovel of mortar cast into a vat sinks down to a common level.

Application of Analysis. — Thus much premised, we have reached the limit of dredging.

The mud and sand which form the channels of the bars yield to the forces that attack it. If any channel could be relieved of its water, whether a dredged or natural channel, it would commence filling, and would ultimately take the level of the prairie marsh.

While attacked by the currents of the river in any pass, it maintains the shape that so much water of the river, with its velocity, is capable of giving it. The moment these forces are changed, the channel changes accordingly; and when the waters desert it for some more favored route, the old one fills; not necessarily from deposit, but from specific gravity, — the universal leveller of the alluvion.

When dredged channels have been made, 3, 4 or 5 feet deeper than the normal channel, the beds are disturbed beneath the waters and beneath the forces of the currents. At once the action commences as if it were out of water. The former condition is assumed as if it had not been disturbed. Much of it returns immediately to its position, only with this difference, that the water which has been partially extruded by time, prior to the disturbance, has been reintroduced, and the mud is the more nearly fluid, and traversable by the keels of vessels. The action of the dredges only disturbs the mud for a few hours (or days perhaps) and it assumes its former position and adhesion.

Jettees. — An extension of this doctrine would be unfavorable to the jettee success, if not fatal to them.

It is plain that the force applied to the bar by jettees, will move the mud to the depth due to the plane of descent, and volume of water *within the walls of the jettees*, minus the opposing wall of the sea in front. If more is required than is due to this plane and volume, the jettees will act as a dam to the waters, and they will cease to scour. If the waters have exit around the jettees, they will take that course; and if not, they will overflow the obstacles. In this case, the former will happen; the waters will run around the jettees, down the other passes, or over the banks.

But beyond the jettees the bar will form at once, unless the material is carried away. That it will not be carried far in advance of the jettees can be answered by past experience. Has it been always carried away, or has the bar formed and pushed outward progressively and forever?

The improbability of reaching a littoral current, that has not been doing the work before, at this or any of the many passes, is too great to base an expectation upon, and places the success in the category of experiment. In seven years, perhaps, this experiment will have a solution. The bar will manifest its disposition to form by that time.

The River and Channels above the Passes. — The River Mississippi curves its channel in the alluvion, and narrows it as it comes nearer to the sea.

Let us consider the character of the channel for 100 miles, before it spreads out and sends off the passes; and the manner in which it divides itself, as it comes within the influence of the sea.

At Carrollton, the upper end of this 100 miles, the Hydrometric station of the Delta Survey, the river takes the form very much that it maintains to the head of the passes.

It has 180,875 square feet of cross-section, being 2735 feet wide, at high water, and 2152 feet at low water. It has increased 13,646 feet in section, in 23 years.

The width of the river at the upper side of the Jump, the first water it parts with, seven miles above the head of the passes, is 2650 feet; and it has a section there of 157,277 feet.

Its greatest depth, not abnormal, is about 100 feet in a symmetrical section; though it often reaches a greater depth, and the greatest line of depth may be put at 150.

Form of channel. — It washes a channel into the alluvial bottom, that may be taken as the segment of a circle, whose height is measured by the channel's greatest depth; or the versed sine of the arc for its height, — the depth of the river, — and its chord equal to twice the sine of the same half arc — the surface width of the river.

The same rule may be applied to the section of the passes, or indeed to any section of a stream in an alluvial bed.

Retardation. — The ground perimeter yields friction at the bottom, and the atmosphere at the surface, which together retard the velocity.

Width and depth. — The semicircle would give the greatest possible velocity; but its approach never reaches a greater degree than about 100 feet for the versed sine, and a surface of 2500 feet; for there are few streams that have so great a depth and section as the Mississippi.

Abnormal depths. — There are depths of the abnormal kind, which reach 240 feet.[9] But these occur very rarely, and are supposed to be eddies caused by rupturing the wall of some pocket of

[9] Maj. Boyd, of the U. S. Coast Survey, found 240 feet in the river, a few miles below Bonnet Carre, in 1876; and Capt. Brown, of the U. S. Engineers, found 80 feet in the jetteed channel, where 23 to 30 feet prevailed above and below.

quicksand, and not continuous channel scoured by the current. These occur near above Fort Jackson, 40 miles from the mouth, at some two miles below Bonnet Carre, and possibly at Natchez. At Cubitt's Gap, one of the gorges sinks to 127 feet opposite the river of only 56 feet greatest depth. This gorge expires almost immediately on leaving the river. The flat shown in the diagram supervenes, and the discharge of the Crevasse has but little channel, out to the level of the sea, say seven miles.

Formation of the Passes.—As the river approaches the level of the Gulf, it exhibits the retardation of its current, and begins to spread its waters and to flatten the segment of the circle which its channel represents.

From the Jump to Cubitt's house, 5.5 miles, it widens from 2660 feet to 4750 feet; and again in the next two miles, it widens to 7500 feet; and it then divides into the three passes of 67,000, 19,350 and 60,267 feet section, having a breadth 1444, 1245, and 827 feet.

Creation of New Passes: the Jump.—Until about the year 1840, there were but three passes. But in the winter and spring of 1839–40, a great flood, Wilder canal opened by crevasse through some hundred yards of distance, and in ten years it attained 1250 feet breadth and 32 feet mean depth,[10] and 45,000 feet of cross-section.

From a survey made by the writer in 1875, the Jump has a channel of 600 feet wide, and divides with 2.5 miles from the river into five channels, or passes, all of which have definite currents, and three of which are navigable for ten miles. One has been navigated out to sea, but generally their bars are soft mud and only one or two feet of depth. The section of the Jump at the present, 1876, is 600 feet × 31 feet—18,550 square feet. It has diminished by more than half its capacity for outlet, and still promises to continue till its several passes become one, or perhaps entirely disappear.

It has reclaimed, and clothed with a forest of willows and cotton woods, an area of 200 square miles. On several of the branches of the main stream there are inhabitants cultivating rice and corn, and raising cattle and hogs. The former depth of the Gulf in this quarter was from 3 to 10 × 12 feet, which has been filled, and the

[10] Ricker Survey, by Prof. Forshey.

alluvion spread out beneath the waters of the Gulf has an unknown extent.[11]

These two, the Jump and Cubitt's Gap, each may make a Pass under the influence of obstructions, artificial or natural, occurring in one or several of the main passes.

In like manner the Oyster Canal was used by Dick Cubitt, till 1862. It broke or was cut through and enlarged, and in a few years became a vast outlet. Its width in 1875 was 1492 feet, its cross-section 30,940 feet, and its discharge about 25,517 cubic feet. Its depths and gorges exhibit such extraordinary extremes of abruptness in channel,—so we have seen above, as to be worthy of remark.[12]

Minor Passes.—Below the head of the main passes, we recognize upon the map, recently corrected and brought up to date, no less than 38 minor passes of all divisions. Of these the Southeast Pass has 9, the South Pass 3, and the Northeast Pass 26 passes. Most of these are but temporary in their location and character, and are answering their functions of filling with sediment the residuary bays, and assisting to bring up the rear of the Delta.

Thus the Mississippi distributes and disposes of its waters and sediments, and makes alluvial country.

Growth and Decadence of the Passes.—The passes are continually altering their relations to each other and to the whole river. The Southwest Pass manifestly grew from the survey of Capt. Talcott in 1838 to Forshey's survey in 1850. The relations were 40 and 45 per cent. of the whole river, while the Northeast Pass diminished from 52 to 47 per cent. The North Pass, Balize Bayou, and Southeast Pass decreased in favor of Pass a l'Outre. These last, however, are but branches of the Northeast Pass. The South Pass was not noticed by Capt. Talcott. It seemed too insignificant then to be measured. In 1850, Prof. Forshey gives it 8 per cent. by cross-section of the whole volume.

Again, Major Howell, to whom I am indebted for many recent facts and sketches, made an elaborate survey about the mouths of

[11] Surveys of Prof. Forshey, in 1875, and H. C. Collins, under Maj. Howell's direction in 1876.

[12] The gap is overgrown with willows and has made several large channels; and the area of alluvion made by its efflux is measured at 3000 acres, in 1877. The operations upon the passes, for the benefit of the jettees, increase vastly the efflux from the Gap, and *may* make a permanent Pass.

the river, and with the results that are set forth in the table below. The Southwest Pass had shrunk to 38 per cent., the Northeast Pass to 42, and the South Pass had grown to 15 per cent.; and then as a product of the works upon it, it had shrunk back to 13

TABLE SHOWING THE GROWTH AND DECADENCE OF PASSES FROM 1838.

Authorities.	Passes. 1838.	Per cent of River.	Length. Miles.	D'pth of Pass. ft. Mean.	D'pth of Pass. ft. Max.	Width. Mean.	Width. Least.	Cross Section.	Discharge ft. per second.	Bar. Feet. Depth.	Bar. Feet. Width.	Remarks.
Capt. A. Talcott, U.S. Engs.	South-west.	.40	15.2	70	162	1200	....	65.000	342.692	13	5000	At the head of Pass, 36 ft.
Capt. A. Talcott, U.S. Engs.	South.	.09	11.28	....	53	700	550	.....	80.761	8	....	At head, 19 feet.
Capt. A. Talcott, U.S. Engs.	Upper North-east.	.52	16.00	....	44	....	....	.....	467.571	13	....	In 1810, 12 feet.
Capt. A. Talcott, U.S. Engs.	South-east.	....	.....	....	....	....	....	.....	78.914	11	....	At head, 42 feet.
Capt. A. Talcott, U.S. Engs.	Balize.	....	.....	....	....	....	....	.....	14.612	....	....	.....
Capt. A. Talcott, U.S. Engs.	a l'Outre.	....	15.00	....	....	....	....	.....	195.755	12	....	.....
Capt. A. Talcott, U.S. Engs.	Whole River.	1.00	.....	....	....	....	....	.....	809.565	....	....	.....
Prof. Forshey.	1850. South-west.	.45	16.2	52	....	1160	....	¾ mile down. 73.452	.....	15	5000 +−	.....
Prof. Forshey.	South.	.08	.....	29	45	....	....	12.960	.....	hd. 24 m. 7	....	.....
Prof. Forshey.	Upper North-east.	.47	16.5	51	....	....	...	75.360	.....	8	7000	.....
Prof. Forshey.	a l'Outre.	.23	15.5	34	....	1140	....	38.896	.....	11	7000	.....
Prof. Forshey.	Jump.	....	5.0	32	42	1250	1250	45.000	.....	3	....	.....
Prof. Forshey.	Whole River at Fort Jackson.	1.00	.....	....	....	2371	....	163.341	.....	....	....	.....
Maj. Howell & H. C. Collins.	1874–5. Whole River at Fort Jackson.	1.00	.....	66	150	2660	....	Above Jump. 157.277	Delta Survey. 1183.500	....	....	.....
Maj. Howell & H. C. Collins.	November, 1875. South-west.	.38	18	48	66	1215	1245	60.227	315.028	drg 18.5	....	Nat. channel 12.5 to 13.5
Maj. Howell & H. C. Collins.	April 27, 1876. South.	.135	13.2	26	32	827	525	21.218	82.027	14±	....	.....
Maj. Howell & H. C. Collins.	November, 1875. North-east.	.42	15.5	46	82	1444	....	66.360	309.700	....	....	.....
Maj. Howell & H. C. Collins.	September, 1875. a l'Outre.	....	10.0	30	75	1208	1080	41.032	.....	11	....	.....
Maj. Howell & H. C. Collins.	September, 1875. Jump.	.12	10±	30.6	52	....	600	18.550	54.402	....	....	.....
Lieut. Davis, Nov., 1875.	November, 1875. Cubitt's Gap.	.12	.....	4	108 127	....	....	18.623	25.517	....	....	.....
Maj. Howell, per Collins.	1877. South-west Pass.	.40	18	....	....	...	....	57.390	276.670	....	....	.....
Maj. Howell, per Collins.	May 29, 1877. North-east Pass.	.428	15.5	....	....	....	....	66.995	293.000	....	....	.....
Maj. Howell, per Collins.	May, 1877. South Pass.	.172	13.2	....	....	....	....	19.350	69.900	....	....	.....

per cent.[13] Bayley gives one section of 15, and one of 12 per cent. in 1875.

Dynamic Law.—The law of dynamics of current tends to keep the passes of nearly the same length, or to close them.

Hence the South Pass, which is three miles shorter than any other, and five miles shorter than the Southwest Pass, should be expected, in a state of nature, to increase for the next century perhaps.

There exists some law which we can approximate, but cannot entirely command, which fixes the relative length of the passes. That law involves the (*wetted*) perimeter, the cross-section, and the slope.

The larger the volume passed out, and the nearer that volume approaches to the semicircle in its section, the less the resistance from its bottom and the atmosphere.—and the less the retarding effect of the sea, as the river approaches it. The greater the volume, the more ability has running water to erode the bottom; and as I believe, the nearer the section approaches the semicircle (or semi-ellipse; *i. e.*, the greater the arc at the point of equilibrium of forces, the greater the moment.

When the river in motion meets the standing wall of water presented by the sea, its ability to displace the obstacle is dependent upon its specific gravity multiplied by its velocity. The river water is lightest, and rises upon the salt water. Just at what angle I am unable to determine. Certain it is, however, that the dead angle has its vertex at this point and that the fresh water does rise upon the salt water; and just as certain that the river, at that

[13] It was a knowledge of these mutations, and especially that the South Pass bade fair to increase for the century to come, from its great lack of length, that the writer of this paper earnestly advocated the choice of the South Pass for the location of any works of internal improvement, especially the jettees, that might be tried upon the river mouths.

And since this Pass has arisen to prominence it may be well to give the state of the head of the Pass in 1850. From Forshey's report in the Ricker survey we extract the following:—

"Above the head of the Pass, and extending near to it, a large sand-bar has formed, bare in low water, which threatens to close the Pass." No island was then in the Pass, but the sand-bar formed the Island. "The soundings from the lower side or left of the head of the Pass give 1 foot, 2, 2.8 feet, 3, 5 fathoms, 4, 5, 5, 7, 4, 3, 8 feet, 8, 7, 3, 3, 4, 4, 4, 2, 5, 4, 4, 2, 5, 3, 2, 1 at shore. Soundings from lower end of bare bar to the upper end or upper side of South Pass: 1, 2, 3, 3, 3, 5, 4, 5, 5, 5, 5, 5½, 5½, 6, 6, 7, 8, 9, 2½ fathoms, 2½, 3½, 4, 3, 4¾, 2¾, 5½, 3½, 2¾, 2 feet at shore. Soundings for cross section ¾ of a mile down: 8 feet at 40 from shore, 2 fathoms 2¼, 55½ 54, 3½, 3½, 3, 3, 3 feet, 2, 1, 20 feet from shore. Section, 12,960."

point, ceases to abrade the bottom; and from that time and place the conflict ceases; here is the outer verge of the bar.

The point of equilibrium is not always the same. It changes with the tides, with the floods in the river, and when not deep, with the winds. The strength of the current, then, is given by the slope and by the volume. The floods give the volume; the slope is always changing; and the problem is too complicated to be formulated.

This conflict is limited to the length of the bar, and chiefly creates it; and is greatest at its crest. Its extent at the passes of the Mississippi is, say, three miles at the Southwest Pass, two at Pass a l'Outre, and one mile at the South Pass. Obviously the bar's length is somewhat dependent upon the volume, in a sediment-bearing river.

When this formula is mastered, we shall be able to compute the normal depth of the channel at any river's mouth; and we shall find that the greater volume of water, with the same slope, will be able to keep the greater depth of water on the bar.

Peculiarities in the Phenomena of the Mississippi.—Some peculiarities that are not known or noticed in other rivers present themselves about the mouths and channels of the Mississippi. These have not hitherto been recorded by Hydrographic writers.

Oblique and Upward Forces.—The banks of the river demonstrate that the material, transported along the bottom, is at times lifted by an oblique or transversely upward movement of the currents and thrown outward upon the banks during overflows, and especially in crevasses in the levees and banks. Much of this matter, chiefly sand and mud balls, is quite too heavy to remain suspended in the river's currents.

This phenomenon is well illustrated upon the channel bars, along the river in its travel up the inclined plane, or inner slope of the sand bars. Otherwise it would never get to sea, and must choke the river's channel.

It is also illustrated in forming the banks of the passes, and even as far out as the verge of the bars. It is lifted or rolled up on the side of the bars, and deposited upon them; and thus commingles to some extent with the clayey matters that are held in suspension until the clay is precipitated by contact with the salt water, and the heavy silt is stopped upon the sides, and assists in forming the permanent alluvion of the bars or banks.

This precipitation takes place the more rapidly on the sides of the passes as they enter the Gulf; the margin of the current colliding and mingling with the salt water, — making eddies and arresting the velocity at both margins along the surface.

It would appear that the lateral discharge from the river's channel in a crevasse, though it be at the surface, is fed from the deep water as well as from the surface; and that these drafts or jets of discharge sweep up the banks of the river from the very bottom, even where the banks are very steep, bearing the heavy silt from the lowest depths of the river along with them, and casting them out into the eddies and quiet waters.

Character of Material on Bars.— Upon the bars proper, there is little of the coarse sand deposited, only that which touches and adheres to clay. The clayey matter forms the body of the bars. The mud or clay is plastic, and has no character of solidity.

Vessels navigating the channels are commonly dragged by the tow boats, the currents, or their own sails or steam, through one or more feet of this clay; and occasionally through two or even three feet, and they leave little or no wake behind them.

Dredging cuts 13 feet of normal depth, to 17 or 18 feet at Pass a l'Outre. And in like manner at the Southwest Pass, as we have seen, where 15 feet normal becomes 18 and 19 feet dredged, and vessels of 20 or 21 feet navigate through it. It closes over three feet of this dredged wake; but the passing vessel slides through it as if it were water or slush.

In short, such is the unconsolidated condition of the channels, about the bars and the river's mouths, that the deepest and most thorough dredging leaves but temporary increased depth of channel.[14] Such is the semi-fluidity or dough-like consistency of the materials of the bars and bank out at sea, that they close over the wake of a vessel that has "wallowed" through several feet of their mud-bottom and channels — in an hour's time, after their passage; and in a few days restore the normal depth, where three or four feet have been cut from the bottom.

[14] We should not omit to notice, that the soundings show hard bottom on the crest of the bar and even across it, when the surface of the bottom only is hard. The vessels plow the bottom in "wallowing" through depths greater than the soundings, indifferent to the fact, if the bottom has been dredged. The sand may have swept along over it, and left the surface coated with sand, so that the lead strikes it as "hard." But the mud beneath is not yet consolidated, — has not had the water extruded from it, that was mixed into it by the pad lles of the dredge, and the vessel passes through easily (or with difficulty) to the sea or to the river.

SEGREGATION OF SILT MATTER.—A very marked segregation of silt material forming the bars takes place on its arrival at the mouths.

The chemical effect of admixture of the chloride of sodium in the sea water is to curdle and precipitate the matter held in solution and suspension, and to throw it down upon the bottom.[15]

The particles of aluminous, argillaceous, or clayey matter, possess adhesive properties to a degree that makes them attach themselves to any matter already on the bottom, to a degree that renders them immovable by the ordinary (or extraordinary) currents at the bar. The water glides over the soft mass at the bottom as if it were soap, without making the least impression upon it.

The sandy particles, on the contrary, are not affected by the chemical causes that precipitate the clayey matter. Nor do they adhere when they reach the bottom. In passing, the sand adheres in a very thin stratum that forms the floor of the great quantity of material delivered. A section of the bar-mud shows generally thin laminæ of sand separating the thick seam or stratum of bar-mud, blue or bluish clay, as if the movement brought different materials; and the thinness of the sand seams would imply the easy transit of sand over sand, as soon as the first floor is established.

This delivery is believed to be chiefly in paroxysms, or alternating pulsations, so to speak. The sand is never or rarely held in suspension. It glides or drifts along the bottom. On reaching the bars these alternations occur. When the river, after a period of lower water, begins to rise rapidly, the energy of the current at the bottom is greatly increased, and the sand which has rested or lagged by the way upon the bottom begins to ascend the inner slope of the bars and to pour over it in profusion. The bar, if not already coated with sand, soon shows *hard bottom*, and the delivery proceeds without obstacle.

This process continues till the accumulation of sand is nearly exhausted, and the normal currents exist on the bars.

This explains why it happens that we have less water on the

[15] A series of experiments made by the writer, in very great numbers, give the following results, they being fair samples of the series. March 15 to March 20, 1876:—

A sample of river water taken, 2 gallons in a jar. When first taken, I could see in it 1.2 inches. After standing 4 days I could see 4.1 inches. I then stirred half a pint of sea water into the 2 gallons. I measured immediately, and could see 1.2 inches as before. In 12 hours I could see 4.1 inches; and again in 2 hours after stirring, I could see 2.5 inches, and in 12 hours I could see 5 inches. I repeated with 2 ounces of salt, with about the same result.

bars in high water. It is because of the delivery of an extra amount of sand.

The amount of sand is believed to be largely in excess of the clayey matter; but from its fineness and freedom from tenacity it is easily moved forward and distributed over the Gulf bottom, by the tidal and wind currents, that are shown to reach considerable depths.

Distribution.—This distribution is twofold. The one described above disposes of the sand on the two banks and on the bottom seaward. The other bears only the lighter matter farther to sea; by holding it in suspension, and keeping it from contact with the salt water, the lightness of the fresh water keeps it on the surface, where it gradually thins out as it goes farther to sea. It is commonly seen 20 miles and occasionally 40 or 50 miles to the leeward of the several mouths.

And this process continues till the whole body is finally mingled with the salt water and loses its aluminous (and finest sand) material. Several days, probably five or ten, elapse before the water is relieved of its turbid burden.[16]

Samples of the Bottom.—The samples of the bottom, taken up in the coast survey, demonstrate, when added to the soundings taken about the mouths of the river by the various U. S. Engineers and assistants, how ample and how extensive are the contributions forming the gently sloping Gulf-shores and proximity for miles in front of the emerged delta. This alone is 147 miles, in the breadth of its sea-front.

Wherever the blue mud is reported, from the Galveston Bay front to the vicinity of Ship and Dauphine Islands, this reports the Mississippi's delivery of its annual—its perennial contributions.

The Alabama river's contributions seem to have covered the white and yellow sand and clays of the "Orange Sand" group, in its outcrop in front of the Mississippi Sound, in some places. But farther out to sea the appearance occasionally of the blue mud will announce the presence of the mud from the Mississippi.

[16] During crevasses of summer, I have often seen the turbid water embayed out of the reach of circulation, holding the last particles of sediment weeks after leaving the river. The last shade is decidedly bluish, and suggests the blue clay, as do the samples we have tried so often in the laboratory.

This is familiarly known as forming the bottom of our ponds and cypress swamps, throughout the alluvion.

Geology of the Depth. — The enormous gorge, or bay, that appears to have existed in the Geological formations of that part of the coast, lying in front of the Mobile Bay and Santa Rosa Sound, is not perfectly understood; that is, whether it is merely a depression in the Super-tertiary, or whether it cuts down into and through the Tertiary beds below.

In either case the Super-tertiary — that is the "Drift" and "Orange Sand" — seems to commingle with the Mississippi mud in the samples examined, and is found to prevail in them, till far to sea.

Such is not the case with the deposit beneath the sea in the Caillou and Galveston Plateau. It is immerged Mississippi mud; and towards the outlet at Florida, even in the profound depth of 5,000 and 10,000 feet, the alluvial material has reported the nature and extent of this distribution.

Mud Lumps. — Along the outer channel, and upon their bars, there occur frequently during the high water period, and occasionally in low water, upheavals of the alluvial bottom of the Gulf, of various dimensions, from a few feet (say 30) in diameter, to five and ten acres in area; and rising often to ten, sometimes fifteen feet above the Gulf level. They have acquired the expressive and descriptive name of *Mud Lumps.*

Their shape is generally spheroidal; never angular, except in great movements. They are unannounced by phenomena, but come with force incalculable. Their depth is unknown, though often sounded 20 or 30 feet, once 90 feet, without any symptom of bottom.

Their rate of elevation is generally slow, though in occasional instances they rise in a few hours, or a single night. Many of them never reach the surface of the water; many expend their force, and sink back to their level; and most of them form permanent additions to the main walls of the channel, and ultimately of the emerged surface of the land.

All these elevations above the alluvial surface of the country are marked by cones and orifices on their surfaces, sometimes two or three feet in dimensions, — whence issue salt water and whitish clay, accompanied by gas jets, sometimes of considerable volume. These jets, and mimic craters, ultimately expire, and the waves wear down the lumps, or they sink by their own specific gravity, to the level of the main shore.

The *mud lumps* are mainly of tenacious clay, precisely like the bar mud; though often more purely aluminous clay.

The gas discharged is always the marsh gas of the country; not rich, but a carburetted hydrogen that burns with a dim flame, and continues at times for hours, though generally the supply is intermittent.

Various hypotheses have been started, and new ones continue to be presented, in explanation of the phenomena. None of these appear to me to account for the phenomena so entirely as that submitted by me soon after my first visit and examination, in 1850.

This hypothesis rests upon geological consideration, imputing the elevations to hydrostatic pressure,— to springs having the artesian character.

Mud-lump Theory. — In the nearest uplands in Louisiana and Mississippi, the "Drift-beds," or diluvial formations, known as the "Orange Sand," have considerable depth, 20′ to 180′, and extend over a large portion of the upland of the states of Mississippi and Louisiana.

In these beds there lie, chiefly at the base of the formation, great strata of pebbles and gravel; and wherever these beds are cut by streams, or penetrated by wells, they yield water abundantly.

They bear the rain water that falls on the surface, and discharge it freely wherever exposed and where not absorbed, and bear it to the bottom of the beds, or to the sea.

This "Orange Sand," or "Drift," passes beneath the other beds, the Bluff-formation, and the Port Hudson group; and extend beneath the alluvion, discharging their waters into the Gulf basin, wherever the outcrop may be.

If we assume, as shown in our analysis of the Gulf basin, that the depths were continued across the Delta, including Lake Pontchartrain and New Orleans, and that the contributions of alluvial matter by the Mississippi river have filled the basin, and projected the shore submerged beyond the mouths of the stream to the depths measured by Talcott, some eleven miles, say 900 feet deep; then, the bottom of the original Gulf is at least 800 feet beneath the present delivery about the mouths. The margin of the deep water is found in the Gulf soundings along about that distance out, for an hundred miles east, and two hundred miles west of the Delta projection. Now the Orange Sand cropped out upon this

slope, and was near the surface; perhaps 50 to 100 feet below the surface at the outer curve, the uplands of Lake Pontchartrain.

The springs are covered and choked by the tenacious clays, thrown down in abundance about the mouths of the river. Thus, whenever one of the subterranean rills is choked by these mud depositions (which must occur in legions), it begins to inject its waters between the lamina of the alluvial bar mud, and to press for discharge, with a lifting power equal to the number of square inches of its surface, multiplied into 15 pounds for every 33 feet of elevation of its source. The tenacity of the mud or clay prevents rupture, up to the point of elevation observed, when the flexure of strata ruptures the seams, and gives escape to the waters and gases confined.

The source of this power in the pebble strata at Natchez, and especially at Ellis Cliffs, rises to 150 feet above the sea level. In a large portion of Mississippi and Louisiana both east and west of the river the same is true, and whenever cut down low enough, the springs appear, and the lifting power reaches an enormous figure, adequate to the phenomena. The theory, then, assigns an adequate cause and claims to account for the phenomena.

The mud lumps have salt water in their craters, said at times to be denser than sea water. This is doubtful, yet possible.[17]

The line of salt springs appears in a large area of upper Louisiana. They dip down with the drift and Orange Sand, and probably discharge some of their saline springs, about the mouths of the Mississippi River.[18]

Geological Features of the Hydrographic Basin of the Gulf.—We know that the earth's surface has been subject to an alternation of elevation and depression: and that this has very quietly changed the location of its bays and seas, its gulfs and even its oceans; so that their present locations are but temporary, geologically speaking. In this respect the Gulf of Mexico is no exception; but wears upon its surroundings, written in rocks, soils and clays, mineral and animal remains, the indelible history of its own mutations and experiences.

[17] This theory of mud lumps and their cause was read before the Academy of Sciences in New Orleans, and variously published for many years.

[18] Since the remarkable movement in Pass a l'Outre, in April, 1875, and subsequent phenomena, the suggestion by Major C. W. Howell, of the U. S. Engineers, of a Glacial (for want of a better term), or sliding movement outward, is one I yield to as highly probable. It does not, however, conflict with my theory, but aids it in the cutting off of submerged channels, and rendering necessary these upheavals.

Most of these have been read and translated by abler students. All honor to their labors. The writer has now been for more than a third of a century tossing his pebbles into their baskets, and reading and writing the monosyllables of this "Testimony of the rocks."

From Bartram in 1776, down to Hilgard in 1871, and Howell in 1875, our contributors directly and indirectly to this now ponderous volume of history, may be numbered by scores.[19]

To describe and enumerate the geological beds which have their remains and ages determined along the river valley, I shall assume the natural order, and mention them generally, without holding myself bound to give details, or to account for exceptions.

These geological beds, each representing an unmeasured, and perhaps immeasurable lapse of time, all dip down not unconformably towards the Gulf, whose waters, lying probably in their present bed, have been contracted and crowded on all their sides but the south, until they now lie in this pyroidal shape, at the foot of the slopes, and are called, "The Gulf of Mexico."

Submerged Alluvion and Bars.—North of the Gulf, and for an hundred miles to the west, and fifty miles to the east of the Mississippi's mouths, above the sea level, and 600 miles in length of Delta, and one hundred or more beneath,—lie the great alluvial deposits,[20] the greatest known to Physical Geography.

From the mouth of East Pearl River, longitude 89° 30′ west, to the mouth of the Vermilion, 92° 71′ west, lies the alluvion of the Mississippi Delta proper; and thence to about ten miles west of the Sabine's mouth, longitude 94° 07′, or 120 miles farther west, the marsh alluvion has a varying breadth of 10 to 25 miles.

[19] I will name, in order as they recur to my memory, those who have materially contributed to the work, and nearly all of whose labors have been personally known to me.

Professors of the Ohio corps of Geologists, Mather, Whittlesey, Hildreth, Locke, Kirtland and Foster. Concurrently,— Featherstonhaugh and Owen, U. S. Geologists; Troost of Tennessee, and Byram Lawrence, of Kentucky and Arkansas; Riddell, Hale, Carpenter, Trastour and Forshey, of the Louisiana corps, 1841. All these made their marks prior to 1813. Then came Sir Charles Lyell, in 1845, and the Shumards, operating from Oregon to Texas, as U. S. Geologists. From this date forward, the aids to the same laborers and their successors, are too numerous to mention.

[20] No other considerable alluvions encroach upon the Gulf, restricting its waters.

The elegantly curved outline of the Gulf, from the Appalachicola Bay to the Rio Grande, seems only disturbed by the great alluvion of the Mississippi Delta.

The Mississippi is the only sediment-bearing river except in freshets, in the whole watershed of the gulf. Hence the Gulf is not rapidly receiving contributions from the other streams, though twenty considerable rivers empty their waters within U. S. Territory, from Appalachicola Bay to the Rio Grande; and twenty small rivers, including the Tuspan, Panuco, the Coatzacoalcos, and the Tabasco, enter from Mexico and Yucatan, the last two with small Deltas, the others almost without them.

Ascending the alluvial bed (called the "Delta") it is rapidly contracted to a width of 40 miles, — say from Opelousas to Port Hudson, 140 miles above New Orleans; and thence to Cape Girardeau, in the state of Missouri, it has a changing breadth of 30 to 90 miles; and a total area of 38,706 square miles, in which it lies in the bed of the former Gulf. It has a variable depth probably nowhere above latitude 30°, much deeper than the greatest depth of the river channel, 80′ to 150′. Towards the river's mouth the alluvial depths are unknown. In the late borings, made by the writer, between the English Turn and Lake Borgne (12 miles below New Orleans) to the depth of 100 feet, marine shells were found in several of them at the depth of 60 feet, and in two instances the white sand of the pine woods (?), possibly of the sea, at 70 to 80 feet. Some of the shells, however, were found in alluvial material, as if the marine shells inhabited it while the alluvion was forming; the borings about the mouths, of 100 feet, having found no indications of other formation than alluvion.

It is highly probable, as shown above, that the alluvial beds here, and south of latitude 30°, fill a much deeper bed of the Gulf, especially westward to Last Island, and far beyond. The alluvial materials, brought up by the coast-survey dredges, show that the ten-fathom line is in alluvion from Vermilion to Pearl River, and Chandeleur. They further show that the same material covers and forms the bottom of the Gulf for many miles and to great depths, spreading fan-like; and continual accretions from the river occur at a measured rate that would build a block of one mile square, 241 feet in height, yearly, as shown by the Delta Survey; and an unmeasured quantity which I put vaguely at three times that amount, or a quantity to build three such columns of sedimentary materials drifted out on the river bottom.

Long prior to the present alluvial era through several consecutive and alternating geological eras, the drainage of the present Mississippi Valley has been along the same valleys, by currents and torrents, and rivers of vastly greater volume, down towards the present great reservoir, the Gulf of Mexico. A gradual elevation of the beds in which the alluvion has been cast, after the river has carved its valley through them, has left the Gulf with its present margin only indented and invaded by the projection of this alluvion, below latitude 30° 21′, as described above.

The Slope of the Delta, Geologically considered. — This it

is believed has never suffered any considerable disturbance since it assumed its present bed. It now inclines somewhat uniformly, across 8° 8′ of latitude, or 564 statute miles, with a total elevation of 322 feet and a mean slope of three-tenths of a foot (.3′) to the mile of channel, or about six-tenths (.6) of a foot to the mile of latitude.

The only geological cataclysm that has occurred in its history, so far as recorded, is that of the New Madrid earthquake, in 1811-12. This is marked by some sunken lakes only three or four feet in depth, and some 50 or 70 miles in length in the western part of the Delta Basin.

But on both sides of this Delta, the formations it cuts through lie consecutively: the Bluff Formation of some 80 feet; the Port Hudson of 180 feet; the Orange Sand of some 250 feet, embracing the Azoic, or life excluding Grand Gulf beds. All these may be, and are, classed as quaternary, or Post-tertiary beds. Their aggregate thickness is probably not less than 700 feet.

Beneath these, but gradually rising in its place lies the Eocene Tertiary, with its vast distribution of Marine Fossils; and then, coming to light beneath these, the Cretaceous beds. These extend from about latitude 34° (?) on the east side of the Delta; and 33° (?) on the west side with many interruptions, especially of the Bluff or drift-beds, to the head of the Delta about Cape Girardeau, in latitude 38° 8′ north.

Here, about, the Carboniferous rocks come up from beneath, and rise to some 300 feet in the next 100 miles.

These formations completely limit the alluvial area termed "the Delta." But through them all, the river erosions from above have brought down their contributions and cast them into the Gulf; and century after century have driven back the waters of the basin; while the whole slope of the greater valley across fifteen degrees of latitude came swelling up from the depths.

This last elevation, after alternations indefinite and periods incalculable, still leaves a drainage for the Mississippi from an area of 1,317,000 square miles, and other streams contribute to the basin 844.000 square miles; thus limiting the vast watershed of the great Gulf of Mexico. These sums added will give an area of 2,161,830 miles in addition to the area occupied by the Gulf itself which is estimated as covering 600.000 square miles.

Into this huge basin the rains of the watershed are drained by

its rivers. That river that passes at our feet, the great Mississippi, pours more than two-thirds of the whole volume into the Gulf.

To the inexorable erosions of this vast watershed, the great chasm is indebted for its gradual but ultimately certain reclamation from the dominion of the sea.

Limit of the Watershed, North and South.— The northern boundary of the Mississippi Valley encroaches so closely upon the margins of the great lakes of the north; and, west of them, cuts abnormally the streams manifestly long flowing into the Gulf, as to impress the conviction of a general elevation of the country along the present limits of drainage, and a rupture of the streams and drying up of the valleys; and a lifting up 1000 or 1500 feet, of the beds of former streams.

The entire hydrographic basin of Lake Winnipeg, and the lakes of the U. S. and Canada that are drained by the St. Lawrence, except perhaps Ontario, was tributary to the Southern Mediterranean prior to this elevation. The marks of former rivers, of great volume, and of wide and deep valleys, are unquestionable testimony.[21]

The elevating process seems not yet completed. A very large district tributary to Lake Winnipeg and indeed from the very summit of the country; the Red River of the North with its vicinage has such vast plains of level marshy surface, as to be uninhabitable; and in all seems to argue the gradual elevation of the beds and depression, perhaps, of the basins.

A similar emergence of the shores of the Gulf of Mexico, along its whole northern and western border, would seem to confirm the hypothesis of a general elevation still in progress, and the prospect that, in the lapse of future centuries, the summit level may be entirely reclaimed from the marshes and the lakes.

Human Epoch.—Man was not introduced upon this portion of the planet, until late in the progress of these stupendous changes.

During the lapse of time between the emergence of the floods of the Glacial and the Drift ages when the bluffs were being deposited by the more tranquil seas, and when the mastodon, mammoth and megatherium were browsing upon the forests of the

[21] See Genl. G. K. Warren's essay upon this subject published by the war department, in 1874, a paper of much instruction and ability—as to the source and valleys of the Minnesota, the Des Plaines and Illinois and Fox Rivers. My own explorations, except as to the Fox River, confirm these views and conclusions.

valley, man also came among them. He soon exhibited his mastery of the giants of the animal creation by slaying the monsters of the land for food.

Testimony of his residence in many places, for example, about the northern shore of Lake Pontchartrain, and upon an island then of the sea now known as part of the mainland, called Petite Anse, there exists a profusion of the vestiges of his works. His arrows, his axes of stone, his hearths for cooking, his bones of slain mastodons, and other animals with the marrow extracted, are found in the piles of shells that ages have accumulated, or in the "Licks" that attracted these animals about the salt rocks then probably lying bare. These resorts invited the daring hunter to seek the game at the salt springs where these huge monsters congregated for the salt waters and sweet clays found there.

From that period to the present time mankind has grown bolder and more enterprising. He has mastered every animal that walked the green earth as his enemy or his companion; has survived, by his superior intelligence and ingenuity, the vast cataclysms that have swept whole races from the earth.

Step by step his own race has aspired to supremacy; has, at various periods by its arts, reduced the fair earth to deserts, and again restored them to fruitful fields and to civilization; each successive race surpassing its predecessor and growing more and more dauntless.

The subjugation of the powers of nature alone seems now to invite his genius and skill. And in this august field he has girdled the mountains and continents with iron bands, and installed in harness of steel and steam his draft-horse and courser. He has lashed his network of wires and cables round the oceans and the earth, that with the very lightnings of heaven he speaks to the antipodes, announces his achievements and proclaims his triumphs.

ADDENDUM.

[The following table was received from Professor Forshey too late to be inserted in its proper place in the text.—EDITOR.]

Cross Sections of the Mississippi River, including a distance of 14 miles of river channel, above, in front of, and below New Orleans. Sounded and measured at intervals of 21 and 22 years (1850 and 1851, and in 1872), on the same lines, by Caleb G Forshey, Civil Engineer.—*From Bayley's discussion of Levees, in Soc. Amer. Engineers.*

SURVEY.					HIGH WATER REFERENCE. DELTA SURVEY GAUGE, AT CARROLLTON.
NO. OF RICKER.	NO. OF DELTA.	1850–51	1872	DIFFERENCE.	
1	56	226,267	233,193	+ 6,926	—{ Upper line of Preston Base, Delta Survey, one mile + above Carrollton. (A).
2	58	227,458	226,877	— 581	—Lower line of same, 400 ft. below.
3	69	209,241	229,325	+20,084	—Upper end of Prime Base. (B).
4	78	189,128	194,915	+ 5,877	—{ Upper end of ordinary Prime Base of Hydrometric operations of Delta Survey.
5	81	186.333	188,160	+ 1,727	—Lower end of same, 200 ft. long. (C).
6	88	184.544	198,302	+13,728	—Upper end of Race Course Base. (D).
7	89	189,260	197,914	+ 7,656	—Lower end of Race Course Base, 400 ft. long. (E).
8	91	177,559	188,075	+10,516	—Upper end of Base at Canal Locks. (F).
9	92	207,236	205,117	— 2,119	—Lower end of same, 400 ft. long. (G).
10	—	155.218	172,125	+16,907	—{ Mean of sections at Fisk's Warehouse, and Steam-ship Landing, compared with sec. at Jackson St., 1872.
11	—	157,861	185,373	+28,512	—Race St., 1850, Virginia Press, 1872. (H).
12	—	184,838	193.875	+ 5,040	—{ Canal St., 1850, compared with Poydras, 1872. (P & C).
13	—	224,176	235.228	+11,092	—Place d'Armes, and Jackson Square. (J).
14	—	214,029	221,072	+ 7,043	—Louisa St., 1872, & Lower Cotton Press, 1850. (L).
MEAN.		186,000	195,525	+ 9,529	

Wind vane Rotations. By J. W. Osborne, of Washington, D. C.

The opinion is very generally held by meteorologists, that the direction of the wind for any particular locality, while oscillating continuously and veering from point to point, completes a larger number of entire revolutions in one direction than in the other. The number of these preponderating revolutions is believed to be small, but tolerably constant; amounting to ten or twelve in the year for places in the temperate latitudes. Their direction in the northern hemisphere is with the hands of a watch; while south of the equator the rotation is in the opposite sense.

The method hitherto employed to investigate this subject has been to note, from the readings of the wind-vane, the amount of shift from one observation to the next following, throughout the series; expressing each in degrees, and calling the change when in one direction (usually that of the watch) positive, and in the other negative. The sum of the arcs, divided by 360, gives the number of preponderating rotations, with its appropriate sign.

It will be seen that the accuracy attained by this method depends upon the frequency of the observations, and upon their correctness. Also, that the gratuitous assumption must be made, that in changing from one point of the compass to another, the vane always passes over the smaller arc: those of 180° being of course lost. In most meteorological observatories, the times for observing are several hours apart, and the intervals are also of irregular duration. The directions of the wind are very frequently obtained from heavy vanes, seriously retarded by friction. Even with such appliances efforts are not always made to obtain a high degree of accuracy, as in the U. S. Signal Service for instance, in which institution only eight points are recorded, whereby a large proportion of changes, involving 180° is occasioned.

Considerations like these suggested the question whether simple mechanical means might not be contrived, by which to get the information sought.

The first and chief requisite was clearly a very sensitive vane, which would take cognizance of the lightest winds. That finally employed proved very satisfactory in this respect, and is constructed as follows:—

The arm is made of the thinnest sheet tin; it is for the most part tubular, terminating in two short, broad blades, diverging

from each other very slightly, and presenting each of them nearly a square foot of surface. The total length of this arm is 5 feet, 4 inches, and it weighs one pound only. It is attached to a vertical steel spindle, and is counterpoised by a piece of lead at a distance of 13 inches, weighing $2\frac{3}{4}$ pounds.

The spindle, $\frac{1}{4}$ inch in diameter, runs through a glass bearing close to the vane. Inside the house its lower end is pointed and hardened, and runs also upon hard glass. This bearing—which is cut away on one side, for a reason that will afterwards become obvious—stands upon the edge of a small raised platform, and the spindle which it supports carries a horizontal pointer which traverses a disk, through which the spindle passes. The disk is supported a short distance above the platform, and upon it a circle is drawn, showing the points of the compass.

Such is the arrangement used for ascertaining the direction of the wind. To determine the preponderating rotations, two methods are employed simultaneously each possessing certain advantages.

The spindle, just above its point, is provided with a small convex pulley or boss, about $\frac{3}{8}$ inch diameter, the surface of which is milled. This revolves and oscillates with the vane; and against its convex surface the flat side of a wheel, 22 inches in diameter, is pressed, by a spring bearing a friction pulley at its end. The wheel is of exceedingly light material, weighing only a few ounces; it revolves in a perpendicular plane, and its axis is immediately below the point of the spindle. One revolution of the vane moves it, forward or backward, the length of the perimeter of the boss at its point of contact. There is no slip, as the flat surface presented to the boss has paper pasted on it upon which the milling bites. This wheel has a cylindrical edge, along which a scale of revolutions and tenths is marked, and numbered both ways, which appears through an opening in the horizontal disk, bearing the points of the compass, and an index is provided to enable the readings to be made.

From this description it will be seen that the direction and number of revolutions, positive or negative from some starting point, and the direction of the wind as well, can be ascertained at a glance at any time.

The other method, to which I referred, is simpler and more accurate, for long intervals; but not so convenient. It consists in

attaching a long piece of fine thread to any suitable part of the upright spindle, fastening a weight of 8 or 10 grains to the other end, and hanging it over a little free pulley, supported at a convenient distance on either side. As the spindle oscillates or revolves, the thread is wound on or off, and the number of turns of the latter, which appear upon it at any time, gives the number of revolutions the vane has made from the last start. This method is not practicable unless the spindle at the part used be of small diameter, not much above $\frac{1}{8}$ of an inch. Both ways of ascertaining the number of rotations can be used together with advantage; the latter is particularly useful for determining corrections on the former; but it is inconvenient where frequent readings are desired, because of the difficulty of counting the coils upon the spindle.

The results obtained from observations (four daily), made with the mechanical appliances I have just described, are remarkable and unexpected. They are as follows:—

Wind-vane Rotations for the Weeks ending

1877.	
April 21,	— 43.9
" 28,	— 41.6
May 5,	— 5.9
" 12,	— 21.1
" 19,	— 4.4
" 26,	— 16.1
June 2,	— 17.8
" 9,	+ 9.8
" 16,	— 7.8
" 23,	— 16.6
" 30,	+ 29.1
July 7,	— 4.4
" 14,	— 42.1
" 21,	+ 3.6
" 28,	— 18.2
August 4,	— 34.7
" 11,	— 10.7
" 18,	— 0.8
" 25,	— 13.9

During the 19 weeks here recorded, 16 of them gave preponderance of negative revolutions, amounting in all to 300; while the

other three gave 42.5 leaving for the whole period — 257.5, or an average of 13.53 per week. Whether this very surprising result may not be conterbalanced by positive revolutions at some other time of year, remains yet to be ascertained.

It may be objected that these numerous revolutions (amounting not unfrequently to 15, 16, or even more in a single day) could be accounted for by supposing vortical eddies of the wind, to act upon the vane. In reply I would say, that the latter was raised about 6½ feet above a flat roof which, except the Capitol, distant 230 yards, was the highest point on Capitol Hill, Washington. That the revolutions may be numerous as well as absent, in calm and also in windy weather, and that as far as can be ascertained at present, their prevalence or direction does not depend upon the presence of a wind from any particular quarter. A study of the way in which a revolution takes place will also dispel the idea that it is caused by a vortical motion as we usually understand it. The vane does not go round in one sweep, but its onward progress is invariably interrupted by many pauses and retrograde movements, occupying sometimes several minutes.

I am far from believing, however, that the construction of the vane, and the configuration of the surface, do not influence these results. A vane which is not delicately suspended will give much fewer of them, and of course if the friction be increased, we shall only have indications from the stronger winds. The weight of the vane is also an important factor in this consideration, for the momentum which it requires, in being moved from one position to another, carries it beyond the point it ought to reach, and if by such means, or partly by such, it traverse more than 180°, and then after a period of calm the leading current sets in again, it will complete the revolution; whereas, but for its momentum, it would have returned over the same arc as that it passed over in its first deflection.

The vane described in this paper was, in relation to its length, exceedingly light; but I am convinced that its weight must be still greatly reduced, and if possible the counterpoise dispensed with, to obtain the best and most reliable results; not only as regards the rotations I have been describing, but for accurate determinations of the direction and veering of the wind as well.

TITLES OF OTHER PAPERS READ IN SECTION A.

Mechanics of the flight of Birds. By A. C. Campbell, of Nashville, Tenn.

The Monetary Question. By E. B. Elliott, of Washington, D. C.

On Standard Time. By E. B. Elliott, of Washington, D. C.

On the Proposed Modifications in the Metric System, in its Introduction into the United States. By T. C. Mendenhall, of Columbus, Ohio.

A Novel Radiometer. By M. Jeffrey, of Lexington, Ky.

Remarks on the Three Meteoric Stones which fell in Indiana, Missouri and Kentucky, during December and January. By J. Lawrence Smith, of Louisville, Ky. (Read in General Evening Session.)

PERMANENT

SUBSECTION OF CHEMISTRY.

PAPERS READ.

THE MINERALS OF A DEPOSIT OF ANTIMONY ORES IN SEVIER COUNTY, ARKANSAS. By F. P. DUNNINGTON, of the University of Virginia.

THE antimony which is consumed in the United States is smelted in Europe from ores brought largely from Borneo, and then imported in the metallic state under a duty of ten per cent. This fact should give encouragement to developing any deposits of antimony in this country.

Previous to the past year, I have *not* been able to find that any ore has been worked for antimony in the United States, save to a small extent some from S. California, a locality which Prof. Dana names, together with one in Nevada, as the only ones in which Stibnite is found in abundance. Otherwise this metal is found only in ores worked for silver, among which I should mention Tetrahedrite of the Kellogg mine in Arkansas.

During the past year I have received from Mr. C. E. Wait, of Little Rock, a number of antimony minerals from a deposit at which there is ore in workable amount, and to him I am also much indebted for a partial description of the locality from which they were obtained.

Within five or six miles of the northeast corner of Sevier County in the southwest of the state of Arkansas, there was discovered by Mr. Batson in 1874, on the east of the Cossatot river, a vein of from four to twenty-four inches in width, with strike N. 13° E., and dip almost vertical. It is known as "Antimony Bluff," and has so far been traced some four or five miles.

About two miles east of this the "Stewart lode" was discovered by Mr. Joseph Stewart in the spring of this year (1877).

Antimony Bluff was first worked by the Little Rock Mining Co., in October, 1876, through an almost vertical shaft from near the top of a high bluff on a two foot vein (I will designate, by numbers, the specimens of ore examined).

To a depth of ten feet antimony ochres Nos. 1, 2 and 3, were obtained; to twenty feet the vein continues transverse to the strata of the rock, though distorted having some glance (No. 4) with the

ochre; below twenty feet, the vein turns to the general direction of the strata of the rock, and has a slaty stratum for its hanging wall, being composed of about equal parts of glance and ochre; at twenty-two feet, the vein narrows to fifteen inches the ochre continuing to decrease in relative amount until, at thirty feet, the vein is thirty inches, and composed of solid glance (No. 5); near this depth is a side four inch vein of No. 6, and also a six inch vein of No. 7; below this a seam of fine grained sulphide No. 8, and also the specimen No. 9 were obtained. At my last advice the vein had been opened to a depth of fifty-five feet.

The Stewart Lode owned by Messrs. Adams, Bostick and others, has not been opened to so great a depth; a vertical shaft 8 × 5 feet and two drifts make it appear of the same nature as the former. From this was obtained a straw yellow mineral No. 10 occurring in very small pieces with the antimony ochre.

No. 1. Light yellow ochre (cervantite) acicular earthy mass, with much silica and alumina.

No. 2. Red orange ochre (cervantite) acicular earthy mass, with small crystals of quartz and a little glance, giving by fire assay seventy-two per cent. antimony and five ounces silver to ton.

No. 3. Orange ochre (cervantite) same acicular earthy mass, very pure: analysis by Mr. J. R. Santos, is published in the "Chemical News," giving: —

Cervantite . . .	96.00
Silica . . .	.92
Moisture . . .	3.08

No. 10. Lemon yellow antimonate of lead (Binheimite) earthy.

Specimen (*a*) compact, gritty, H = 3 — 4.
Specimen (*b*) very soft and smooth, G = 4.73

Analysis by author giving: —

		at. ratio
$Sb_2 O_5$	49.67	1533
Pb O	40.35	1809
$Fe_2 O_3$	2.98	
$H_2 O$	5.98	3323
$Si O_2$	1.14	
	100.12	

As the nature of this species is not fully understood it is of interest to make note here of a fact in connection with the formula, to which this analysis of so pure a specimen lends additional evidence. Taking all the analyses quoted in Dana's mineralogy, designated by the numbers there used, and adding the analysis in discussion as No. 7, we have for the ratios between the number of molecules, making the H_2O 100 or 200:

Nos.	1	2	5	7	3	4	6
H_2O	100	100	100	100	200	200	200
Pb O	76	72	54	54	66	63	55
Sb_2O_5 . . .	27	42	40	46	41	39	44
Pb O + Sb_2O_5 .	103	114	94	100	107	102	99

Now excepting No. 2 as containing some anhydrous Pb O, we note that the number of molecules of water is equal to either once or twice the sum of the molecules of the oxides. And although from the analyses quoted we cannot fix any relation between the oxides, we must recognize two subdivisions of this species as given by the expressions:

$$(x\ Pb\ O + y\ Sb_2O_5) + (x+y),\ H_2O \text{ and}$$
$$(x\ Pb\ O + y\ Sb_2O_5) + 2\ (x+y),\ H_2O$$

Analysis No. 7 giving the formula

$$(Pb\ Sb_2O_6)\ 2,\ H_2O + \tfrac{1}{5}\ Pb\ O,\ H_2O.$$

No. 4. Large crystals of glance coated with yellow ochre, with similar acicular structure and small crystals of quartz.

No. 5. Compact antimony glance (Stibnite) of fine fibrous structure, a sample of the ore which was removed in lumps of 200 to 500 lbs. almost free of quartz. G = 4.498.

Analysis, giving:—

Sb . . .	71.31	(71.8 by formula
S . . .	28.51	28.2)
	99.82	

No. 6. Compact fibrous antimony and lead sulphide with some quartz containing 8 oz. silver to the ton.

G = 5.14, ratio of Pb to Sb = 3 : 4.

Hence probably Jamesonite with Stibnite.

No. 7. Large crystals of Stibnite imbedded in quartz there being about equal portions of each.

No. 8. Very compact antimony and lead sulphide, free of quartz G = 5.33, H = 3 (probably Zinkenite).

No. 9 Compact mass of needle-like crystals, with a faint brown tinge (with quartz) G = 5.19, H = 2.5 of special interest, as containing zinc.

Analysis giving:—

S	22.183 . .	69.5 ratio of atoms.	
Sb . . .	32.888 . .	27. " " "	
Pb . . .	36.780 . .	18. " " "	
Zn . . .	5.072 . .	7.5 " " "	
Fe . . .	2.615 . .	4.5 " " "	
SiO_2 . . .	.743		
	100.281		

To identify the species we have:—

First, including zinc . . . . . R : S + A = 1 : 3.23

Second, excluding Zinc (as ZnS) . . . R : S + A = 1 : 3.94

The only species desc. betw. these limits, have R : S + A = 1 : 3.5

If, therefore, we regard the excess of R as ZnS, deducting 3.18 per cent. of ZnS, we obtain:

R : S : A = 1 : $\frac{5}{2}$: 1 in which there is 2.94 per cent. Zn, giving:

$$2(\tfrac{4}{6}\,Pb + \tfrac{1}{6}\,Zn + \tfrac{1}{6}\,Fe)\;S + Sb_2S_3$$

or 2 (Pb, Zn, Fe) S + Sb_2S_3.

Moreover, deducting the blend, the specific gravity of this mineral = 5.24; and replacing the zinc by lead, atom for atom, we have specific gravity = 5.5, which agrees with the specific gravity of Jamesonite quoted in Dana 5.5—5.8.

			at.	100.	+ 5.24 = 19.080
100	+ 5.19 = 19.27		452 × 97 =	4.380;	+ 4. = 1.095
3.18	+ 4. = .795			95.62	17.985
96.82	+ ? = 18.475		452 × 223 =	10.09 ;	+ 7.5 = 1.345
? G = 5.24				105.71	+ ? G = 19.330
				? G = 5.50	

We must, therefore, admit that this specimen contains Jamesonite in which the iron, with at least an equal amount of zinc, replaces one-third of the lead.

While small amounts of zinc have been found with Jamesonite, in none of the analyses quoted heretofore does it appear to have entered into that mineral.

Of the ore removed from the Antimony bluff vein, the owners shipped in December, 1876, seven tons to Messrs. Hallet & Co. of London, who pronounced it of excellent quality, giving £20 per ton for the glance and £16 for the ochre.

THE ACTION OF DILUTE ACID UPON FERROUS SULPHIDE MADE FROM CAST-IRON. By F. P. DUNNINGTON, of the University of Virginia.

IN the fifth volume of Gmelin's Chemistry, page 215, it is stated that if sulphur be stirred into melted cast-iron, the iron will be converted into white iron, and ferrous sulphide will be found in a crust on the surface.

At the suggestion of Dr. J. W. Mallet, I have endeavored to determine whether ferrous sulphide may be thus made from pig-iron which can be economically employed for making hydrosulphuric acid.

Experiment 1st: Melted cast-iron in excess was poured upon some sulphur in a pot lined with moulding clay; most of the sulphur was volatilized, and after cooling the result was:

1°. At the bottom, a mass of crystallized white iron.

2°. A compact layer, about $3^{mm.}$ thick, of fine, light yellow brassy crystals (E).

3°. An easily shattered layer of $2^{mm.}$ of larger bronze colored crystals (C).

Experiment 2nd: Melted cast-iron was poured into almost its own weight of sulphur, and constantly stirred until solid, the result was:

1°. Fragments of white iron, 7 ounces.

2°. Iron sulphides, 11 ounces covered with a grayish brown film of oxide, and consisting of about 50 per cent. of a yellow, partly crystalline portion (A), about 50 per cent. of a mass of fine, light yellow particles (D).

Experiment 3rd: Melted cast-iron in excess was poured into sulphur and constantly stirred until solid; the result was:

1°. Fragments of white iron, 60 ounces.

2°. Iron sulphides, total 23 ounces and consisting approximately of 50 per cent.; a sponge-like mass composed of fine, light yellow particles with a brown and bronze film (G).

20 per cent. fine crystals (H), similar to (E).

20 per cent. a light yellow fused mass.

10 per cent. bronze yellow crystals (B).

For comparison I quote the usual method. A white-hot bar of wrought-iron is brought in contact with a roll of sulphur over water; this fused sulphide falls:

1°. Partly in small beads (K) less than $3^{mm.}$ diameter, which on fracture are crystalline and similar to (B).

2°. Mainly in larger drops (F), a uniform brown gray mass with indistinct brassy lustre.

Owing to the film of oxide formed over most of the specimens, it was difficult to obtain other than small samples for analysis.

The determinations of iron and sulphur were made by fusion with nitre and soda (the Ba SO^4 being carefully purified). The carbon and silicon, not entering into the question, were only determined in the residues after the action of acid.

All the specimens were slightly magnetic.

The color of (A)	yellow,
" " " (B), (C) and (K)	bronze yellow,
" " " (D), (E), (F), (G) and (H) .	light yellow.
Dilute H_2SO^4 acts on (A), (B), (C) and (K)	not until heated,
" " " " G	slowly at first,
" " " " (D), (E), (F) and (H)	immediately.

By analysis we have:

	(A)	(B)	(C)	(D)	(E)	(F)
Fe =	61.16	62.77	64.16	67.10	67.41	70.15
S =	38.00	36.33	35.08	32.77	31.12	27.97
Si&C =	1.17	.10	1.18	.35	1.28	——
	100.33	99.20	100.42	100.22	99.81	98.12

From which we have the ratios between the numbers of atoms making Fe = 100. For the above specimens

S =	109.	101.	96.	85.	81.	70.

Specimens of these were treated with dilute HCl and warmed until all action ceased; some sulphur and a little iron remained with the carbon and silica, viz.:

Per cent. Fe =	1.01	.23	.11	.41[1]	.0	.0
Per cent. S =	6.71	3.80	2.48	.43[1]	.2	.0

Giving the following ratios between the number of atoms of Fe dissolved and S given off as H^2S; making Fe = 100:

S =	91.	91.	89.	85.	80.	70.

It appears that (B), which is so similar to (K), most resembles the pure FeS, in composition, but that (C) though containing less S, evolved a greater per cent. (32.6) of S as H_2S, and that the action of acid upon each of them will not begin without heat.

Moreover, that as the free iron increases in amount the sulphur is more completely given off in the form of H_2S, and the action of the acid is more rapid.

Hence it is not the pure FeS which is desired for making H_2S, but one containing free Fe. Now note that (A) and (D) compose the product of experiment 2nd, and being intermixed, the heat developed by the action of the acid on (D), will cause (A) to be attacked so that it answers very well for the purpose in question.

Therefore by this method commercial ferrous sulphide can, no doubt, be made in large quantities directly from pig-iron; while the loss of two-thirds of the sulphur may be greatly diminished on the large scale, by more regular and thorough mixing of the melted iron and sulphur.

[1] This is evidently an error due to want of acid in digesting, but it was noticed when too late to repeat.

THE VARIOUS METHODS OF SEPARATING AND DETERMINING BARIUM, STRONTIUM, AND CALCIUM. By PAUL SCHWEITZER, of Columbia, Mo.

II. DETERMINATION OF STRONTIUM.

STRONTIUM is generally precipitated from its solutions as sulphate or carbonate, and weighed as such, the determination as nitrate being preferred only in special cases. The general characteristics of the salts of strontium are very much like those of barium; the same precautions must be observed in their precipitation, and the same affinities, though perhaps in a less degree, exist between them and the salts of the alkalies. In incinerating the paper, on which precipitates of strontium have been filtered, special care must be taken to remove the precipitates as much as possible from it, and to burn it at a comparatively low temperature on account of the volatility of the strontium salts.[1] This volatility is especially noticeable in the hydrous salts, as we obtain them by precipitation and subsequent drying. In fact, the precipitated and dried salts of the alkaline earths differ in a marked degree from the ignited precipitates, and some of the minerals we find in nature, a fact which promises interesting results on closer study.

For all determinations of strontium, unless otherwise stated, pure strontium chloride[2] was employed, and as it was impossible to obtain it of known composition,[3] a special determination of the amount of strontium in it was made for each experiment or set of experiments, by evaporating its solution in a platinum crucible

[1] Boussingault, Comp. Rend. LXIV, 1159, and M. Darmstadt, Zeitschrift f. analyt. Chem. VI, 376.

[2] To obtain it, the purest salt of Merck in Darmstadt was subjected to the following process; a little dilute sulphuric acid was added to its solution in water, and the whole boiled for half an hour; after settling, the clear solution was separated from the precipitate, containing all the barium that might have been present, and evaporated to crystallization; the first crop of crystals was rejected, as perhaps still containing traces of barium, and the subsequent crystallizations collected, taking care, however, to leave about one-half of the amount of the salt in the mother liquor. These crystals, containing probably only traces of lime were dissolved in water, the solution boiled with a little ammonium oxalate, and the filtrate from the precipitate formed, after adding a few drops of hydrochloric acid evaporated to dryness. This mass was digested three times with alcohol, and the residue from this dissolved in water, filtered and evaporated to dryness; it was then pulverized and heated in a water bath, until it seemed perfectly dry, when it was placed in a glass-stoppered bottle and this again in an empty desiccator; the spectroscope revealed in it no traces of barium or calcium.

[3] The removal of water by drying is much more difficult than in the case of barium chloride, as it requires a long continued gentle heat, which must be applied very grad-

with pure dilute sulphuric acid, and igniting the residue. It was found necessary to repeat this operation a second time, to insure complete conversion of the chloride into sulphate, as without it

ually; if these conditions are not observed, much chlorine is volatilized, which can only be restored again with difficulty and trouble. Observe the following experiments;

2.8000 gr. strontium chloride from bottle lost on gently heating, so that the bottom of the crucible did not become red hot

0.0484 gr. water = 1.73 p. c. after 10 minutes.
0.0484 gr. " = 1.73 p. c. " 15 "
0.0484 gr. " = 1.73 p. c. " 25 "
0.0470 gr. " = 1.68 p. c. after heating with N H_4 Cl.
0.0436 gr. " = 1.56 p. c. " repeating the process.
0.0436 gr. " = 1.56 p. c. " " " "

after evaporation with dilute sulphuric acid and ignition it yielded

3.1166 gr. Sr SO_4; after repeating the operation
3.1920 gr. " " " "
3.1920 gr. " = 2.7564 gr. Sr Cl_2, equal to 1.56 p. c.

of water in the original substance. It gave up to water no trace of chlorine.

3.0555 gr. strontium chloride from bottle lost by gently heating like the previous one

0.0501 gr. water = 1.64 p. c. after 10 minutes.
0.0503 gr. " = 1.65 p. c. " 15 "
0.0510 gr. " = 1.67 p. c. " 20 "
0.0513 gr. " = 1.68 p. c. " 25 "
0.0515 gr. " = 1.69 p. c. after 5 minutes at a higher temperature.
0.0474 gr. " = 1.55 p. c. " heating with N H_4 Cl.

after evaporation with dilute sulphuric acid and ignition it yielded

3.3780 gr. Sr SO_4; after repeating the operation
3.4039 gr. " ; " " " "
3.4275 gr. " ; " " " "
3.4675 gr. " ; " " " "
3.4835 gr. " ; after heating with $Am_2 CO_3$
3.4835 gr. Sr SO_4 = 3.0081 gr. Sr Cl_2, equal to 1.55 p. c.

of water in the original substance. It contained no trace of chlorine.

2.3282 gr. strontium chloride from bottle lost by heating like the previous one

0.0382 gr. water = 1.64 p. c. after 5 minutes.
0.0377 gr. " = 1.62 p. c. " 10 "
0.0383 gr. " = 1.64 p. c. " 15 "
0.0367 gr. " = 1.58 p. c. after heating with N H_4 Cl.
0.0358 gr. " = 1.54 p. c. " " " "

The salt dissolved in water to a clear solution, which was not alkaline.

4.0515 gr. strontium chloride from bottle lost on heating at a higher temperature, than employed previously

0.0930 gr. water = 2.29 p. c. after 5 minutes.
0.0933 gr. " = 2.29 p. c. " 10 "
0.0959 gr. " = 2.37 p. c. after heating to fusion.
0.0948 gr. " = 2.34 p. c. " " with N H_4 Cl.
0.0938 gr. " = 2.31 p. c. " repeating the operation.

The salt dissolved turbidly in water and showed an alkaline reaction; it seemed not possible, to restore to it after fusion, all the chlorine it had lost.

and alcohol, necessary for the purification of the precipitates, using a little only at a time, was about 100 c. c. for each; the filter papers were in no case carbonized by drying, but the precipitates showed upon incineration at a low temperature, a pronounced tendency to dusting, caused by the removal of chemically combined water of a slightly acid reaction, a fact which I do not consider an argument for the presence of strontium disulphate, but as indicating merely an impurity.

After incineration the precipitates presented the appearance of light, porous masses, resembling calcium sulphate or magnesium carbonate, easily falling into a fine powder, when placed in water, and giving up to the latter, even after acidulating with a few drops of nitric acid, no traces of chlorine, indicative of the entire absence of occluded strontium chloride. The results are as follows:—

1. 1.6368 gr. $SrCl_2$[6] = 1.0677 gr. SrO
   1.8842 gr. $SrSO_4$ = 1.0614 gr. " = 99.41 p. c.
2. 1.0480 gr. $SrCl_2$ = 0.6837 gr. "
   1.2096 gr. $SrSO_4$ = 0.6813 gr. " = 99.65 p. c.
3. 1.6368 gr. $SrCl_2$ = 1.0677 gr. "
   1.8879 gr. $SrSO_4$ = 1.0635 gr. " = 99.61 p. c.
4. 1.6368 gr. $SrCl_2$ = 1.0677 gr. "
   1.8873 gr. $SrSO_4$ = 1.0631 gr. " = 99.58 p. c.

In making in the same way two further experiments, except stopping the washing, when about all sulphuric acid had been removed from the precipitates, but when they still contained some hydrochloric acid, the following results were obtained:

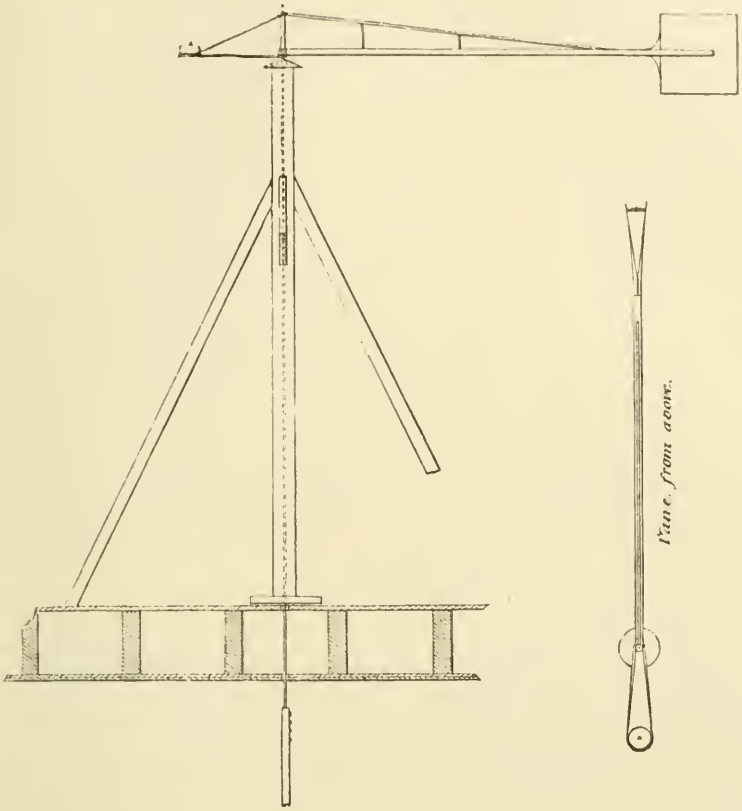
1. 0.3931 gr. SrCl = 0.2564 gr. SrO
   0.4565 gr. $SrSO_4$ = 0.2572 gr. " = 100.31 p. c.
2. 1.0353 gr. $SrCl_2$ = 0.6754 gr. "
   1.2034 gr. $SrSO_4$ = 0.6779 gr. " = 100.37 p. c.

The cause of the excess here over the former (the plus over 100 p. c. is owing to error) is occluded chloride, which, as in the case of barium chloride, is washed out after the sulphuric acid has disappeared from the wash-waters (see Part I, *I. a First Series*). In the first four analyses the washing had been continued until all occluded chloride had been removed; therefore the loss.

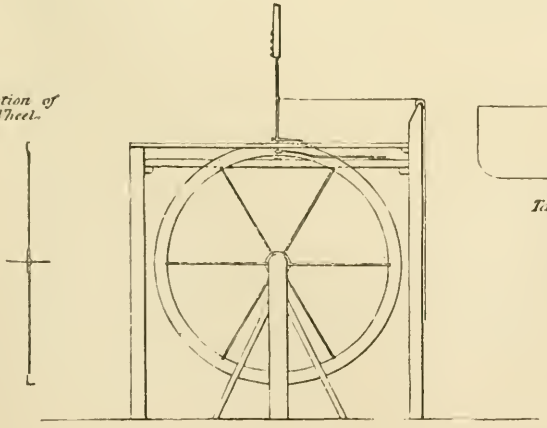
In precipitating a solution of strontium nitrate in the way just

[6] In analyses 1, 3, 4 and others, the quantity of strontium chloride taken was measured off from a solution of a weighed quantity of it in water; wherever that has been the case is readily recognized.

WIND-VANE ROTATIONS.



Vane from above.



Section of Wheel.

Table from above.

described under 1 to 4, using more and more sulphuric acid, a trifle higher figures were obtained, probably on account of strontium sulphate not being quite so readily soluble in nitric as it is in hydrochloric acid; these are the results:—

1.	0.7680 gr. Sr $(NO_3)_2$	= 0.3753 gr.	SrO	
	0.6675 gr. Sr SO_4	= 0.3760 gr.	"	= 100.19 p. c.
2.	2.1924 gr. Sr $(NO_3)_2$	= 1.0729 gr.	"	
	1.8990 gr. Sr SO_4	= 1.0711 gr.	"	= 99.83 p. c.
3.	2.5422 gr. Sr $(NO_3)_2$	= 1.2441 gr.	"	
	2.2000 gr. Sr SO_4	= 1.2409 gr.	"	= 99.74 p. c.
4.	2.4353 gr. Sr $(NO_3)_2$	= 1.1917 gr.	"	
	2.1000 gr. Sr SO_4	= 1.1845 gr.	"	= 99.40 p. c.
5.	1.9570 gr. Sr $(NO_3)_2$	= 0.9563 gr.	"	
	1.6843 gr. Sr SO_4	= 0.9488 gr.	"	= 99.22 p. c.

It will be seen that water alone is sufficient to remove all occluded strontium salt, which was not the case in the barium precipitates.

2. *Second Series.*

Six experiments were made to determine in what manner solutions of strontium were affected on precipitation as sulphate by the presence of other salts, especially those of the alkalies. Smaller amounts, as was stated by me some years ago, are retained by strontium sulphate than by barium sulphate, except in the case of potassium salts, which give rise to the formation of a regular compound in equal molecular quantities, insoluble in dilute alcohol and potassium sulphate, but soluble with decomposition by water; similar compounds exist no doubt of rubidium and cæsium though I had not the means of verifying it.

Strontium chloride was dissolved in 200 c.c. of water, a few drops of hydrochloric acid and 3 gr. of the chlorides of the salts under examination were added to each solution, and lastly a sufficient amount of dilute sulphuric acid with an equal volume of alcohol; after standing for twenty-four hours the precipitates were filtered, washed with a mixture of alcohol and water, dried and ignited. I may say here, that the alcohol was in no case sufficient to precipitate any portion of the salts added, the amounts of them retained being solely retained by molecular attraction. For No. 1 were

consumed about three litres of wash-water in about four weeks' time, to remove all the chlorine present, during which the precipitate shrunk in volume and lost its slimy character; No. 2 was washed with about one litre and the others with 200 c. c. of liquid, to free them completely from chlorine; the results are as follows:—

1. 1.6368 gr. $Sr\,Cl_2$ (3 gr. KCl) = 1.0677 gr. SrO
   3.1052 gr. $Sr\,SO_4 + K_2\,SO_4$[7]
   1.8955 gr. $Sr\,SO_4$ = 0·0207 Mol. = 1.00 Mol.
   1.2097 gr. K_2SO_4 = 0·0138 Mol. = 0.67 Mol.
2. 1.6368 gr. $Sr\,Cl_2$ (3 gr. Na Cl) = 1.0677 gr. SrO
   1.9124 gr. $Sr\,SO_4$ = 1.0773 gr. " = 100.90 p.c.
3. 1.3561 gr. $Sr\,Cl_2$ (3 gr. $Mg\,Cl_2$) = 0.8846 gr. "
   1.5769 gr. $Sr\,SO_4$ = 0.8883 gr. " = 100.42 p.c
4. 1.4281 gr. $Sr\,Cl_2$ (3 gr. $Zn\,Cl_2$) = 0.9316 gr. "
   1.6663 gr. $Sr\,SO_4$ = 0.9386 gr. " = 100.75 p.c.
5. 1.2015 gr. $Sr\,Cl_2$ (3 gr. $Al_2\,Cl_6$) = 0.7838 gr. "
   1.4000 gr. $Sr\,SO_4$ = 0.7887 gr. " = 100.62 p.c.
6. 1.5280 gr. $Sr\,Cl_2$ (3 gr. $Fe_2\,Cl_6$) = 0.9967 gr. "
   1.7809 gr. $Sr\,SO_4$ = 1.0032 gr. " = 100.65 p.c.

After ignition all precipitates gave up to boiling water larger quantities of sulphuric acid than was owing to dissolved strontium sulphate; No 1 of course more than the rest; they were free from chlorine, except probably No. 6, which was not tested with hot dilute nitric acid.

In precipitating strontium nitrate in the presence of potassium chloride by dilute sulphuric acid and alcohol, and washing as before described, results are obtained in every way similar to those obtained with strontium chloride.

1. 1.1100 gr. $Sr\,(NO_3)_2$ (3 gr. K Cl) = 0.5424 gr. SrO
   1.5562 gr. $Sr\,SO_4 + K_2\,SO_4$
   0.9629 gr. $Sr\,SO_4$ = 0.0105 Mol. = 1.00 Mol.
   0.5933 gr. $K_2\,SO_4$ = 0.0068 Mol. = 0.65 Mol.
2. 1.6696 gr. $Sr\,(NO_3)_2$ (3 gr. K Cl) = 0.8158 gr. SrO
   2.3906 gr. $Sr\,SO_4 + K_2\,SO$
   1.4482 gr. $Sr\,SO_4$ = 0.0158 Mol. = 1.00 Mol.
   0.9424 gr. $K_2\,SO_4$ = 0.0108 Mol. = 0.68 Mol.

[7] H. Rose, Pogg. Annal. XCIII, p. 1.

3. *Third Series.*

The influence of alkalies was further investigated by precipitating a solution of strontium chloride with various alkaline sulphates; the salt was dissolved in 200 c.c. of water, and after acidulating with hydrochloric acid precipitated by an excess of alkaline sulphate; an equal volume of alcohol was then added and the whole allowed to stand for twenty-four hours, when the precipitates were brought upon their filters, washed until all chlorine had disappeared, dried and weighed. All precipitates looked at first bulky and somewhat slimy, but changed soon in appearance, quickest the precipitate by ammonium sulphate, which differed not in the least from barium sulphate. Nos. 1 and 2 required again large quantities of washing-liquid to free them from chlorine.

1. 1.3294 gr. $Sr\,Cl_2$ ($K_2\,SO_4$ = 0.8673 gr. SrO
   2.7127 gr. $Sr\,SO_4 + K_2\,SO_4$[8]
   1.5426 gr. $Sr\,SO_4$ = 0.0168 Mol. = 1.00 Mol.
   1.1701 gr. $K_2\,SO_4$ = 0.0134 Mol. = 0.80 Mol.
2. 0.3922 gr. $Sr\,Cl_2$ ($K_2\,SO_4$) = 0.2559 gr. SrO
   0.8244 gr. $Sr\,SO_4 + K_2\,SO_4$
   0.4542 gr. $Sr\,SO_4$ = 0.0049 Mol. = 1.00 Mol.
   0.3702 gr. $K_2\,SO_4$ = 0.0042 Mol. = 0.86 Mol.
3. 1.3294 gr. $Sr\,Cl_2$ ($Na_2\,SO_4$) = 0.8673 gr. SrO
   1.5608 gr. $Sr\,SO_4$ = 0.8792 gr. " = 101.37 p. c.
4. 1.3294 gr. $Sr\,Cl_2$ ($[NH_4]_2\,SO_4$) = 0.8673 gr. "
   1.5426 gr. $Sr\,SO_4$ = 0.8690 gr. " = 100.19 p. c.

The ignited precipitates gave up to boiling water no chlorine.

[8] Another experiment was made by precipitating a solution of strontium chloride with an excess of potassium sulphate in the cold and without alcohol; the precipitate looked bulky at first, but changed in a few days into a mass of needle-shaped crystals; they were brought upon the filter with their own solution, and washed three times with alcohol and water; after removal from the dried filter paper, they were ignited without the latter, giving the following result:

1.7577 gr. $Sr\,Cl_2$ ($K_2\,SO_4$) = 1.1462 gr. SrO
3.9483 gr. $Sr\,SO_4 + K_2\,SO_4$
2.0354 gr. $Sr\,SO_4$ = 0.0222 Mol. = 1.00 Mol.
1.9129 gr. $K_2\,SO_4$ = 0.0220 Mol. = 0.99 Mol.

Boiling water extracted from it only traces of chlorine, but abundant sulphuric acid; the compound, as stated, is insoluble in dilute alcohol and alkaline sulphates, but decomposable by water, so that by sufficiently long washing with water alone, approximate results may be obtained; compare the following result:

1.9990 gr. $Sr\,(NO_3)_2$ (3 gr. KCl + 3 gr. Na Cl) = 0.9328 gr. SrO
1.6370 gr. $Sr\,SO_4$ = 0.9222 gr. " = 98.86 p. c.

This precipitate had been washed, until the wash-water gave a cloudiness with barium chloride only after a few seconds.

4. *Fourth Series.*

On reversing the process, that is precipitating a solution of potassium sulphate by strontium chloride, adding an equal amount of alcohol, and filtering after twenty-four hours' standing, and washing with dilute alcohol, until nearly all (No. 1) or all (No. 2) sulphuric acid had been removed, a loss is experienced, caused as in the case of barium, by the occlusion and subsequent removal by washing of potassium sulphate:

1. 0.5478 gr. K_2SO_4 = 0.2516 gr. SO_3
   0.5731 gr. $SrSO_4$ = 0.2503 gr. " = 99.48 p. c.
2. 1.5847 gr. K_2SO_4 = 0.7278 gr. "
   1.6497 gr. $SrSO_4$ = 0.7204 gr. " = 98.98 p. c.

The greater loss in No. 2 is caused by longer continued washing, and could have been prevented by collecting the wash-waters evaporating them to a suitable volume, adding again some alcohol and filtering off the precipitate, which would have been sure to form.

5. *Fifth Series.*

Some experiments were made to determine the degree of accuracy, obtainable, in precipitating salts of strontia in the cold with dilute sulphuric acid without alcohol, a thing that may happen in the analysis of barium minerals, in which the presence of strontium is not suspected; it would give rise to a deficiency of course, which, however, might not be such as to evoke challenge. Different amounts of strontium chloride were dissolved to this end in 500 c.c. of water, and precipitated by increasing amounts of dilute sulphuric acid, taking in No. 1, 5 c.c.; in No. 2, 10 c.c.; in No. 3, 15 c.c.; in No. 4, 30 c.c. The same quantity was taken in Nos. 5 and 6, but to the former had been added in addition 10 c.c., and to the latter 20 c.c. of hydrochloric acid, containing 16 p. c. of HCl. All precipitates were washed with cold water until they were free

from chlorine; 5 and 6 appeared perfectly crystalline, almost adhering to the sides of the glass in crusts; these were the results:

1. 0.3424 gr. $SrCl_2$ = 0.2234 gr. SrO
   0.3925 gr. $SrSO_4$ = 0.2211 gr. " = 98.97 p. c.
2. 0.6849 gr. $SrCl_2$ = 0.4468 gr. "
   0.7870 gr. $SrSO_4$ = 0.4433 gr. " = 99.17 p. c.
3. 1.3697 gr. $SrCl_2$ = 0.8935 gr. "
   1.5828 gr. $SrSO_4$ = 0.8916 gr. " = 99.79 p. c.
4. 2.7395 gr. $SrCl_2$ = 1.7871 gr. "
   3.1674 gr. $SrSO_4$ = 1.7842 gr. " = 99.84 p. c.
5. 0.6849 gr. $SrCl_2$ = 0.4468 gr. "
   0.7826 gr. $SrSO_4$ = 0.4412 gr. " = 98.75 p. c.
6. 0.6849 gr. $SrCl_2$ = 0.4468 gr. "
   0.6156 gr. $SrSO_4$ = 0.3468 gr. " = 77.62 p. c.

It was difficult in these cases to incinerate the filter papers, which were saturated with the aqueous solution of strontium sulphate.

In like manner two experiments were made with strontium nitrate; No. 1 was a neutral solution, No. 2 a solution acidulated with hydrochloric acid; after precipitation No. 1 was merely washed with water, while No. 2 was twice boiled with hydrochloric acid, as described under barium, and then washed to the removal of chlorine:

1. 2.1860 gr. $Sr(NO_3)_2$ = 1.0682 gr. SrO
   1.8667 gr. $SrSO_4$ = 1.0515 gr. " = 98.44 p. c.
2. 2.4942 gr. $Sr(NO_3)_2$ = 1.2187 gr. "
   2.0483 gr. $SrSO_4$ = 1.1538 gr. " = 94.68 p. c.

APPENDIX.

I. Solubility of strontium sulphate in water.[9]

The solubility of strontium sulphate in water was determined by digesting the pure salt in water either in the cold or after heat-

[9] Compare: Kremers, Pogg. Annal. LXXXV, 247 . . . 1:5345 at 15° C; Gmelin, Handbuch . . . . . 1:3600 at 15.5° C; Berzelius, Lehrbuch Vol. III, pg. 386 . . . 1:3600 at 100° C; R. Brandes and Silver, Brande's Archiv. 1830, XXXIII, 61 . . . 1:15029 at 11.25° C and 1:3544 at 100° C (figures taken from Storer, Dict. of Solub., who remarks that they do not agree with the details of the experiments); Fresenius, Annal. Chem. and Pharm. 1846, LIX, 121 . . . 1:6895 at 14° C and 1:9638 at 100° C.

ing, and evaporating 500 c. c. of the solution in a large platinum dish and igniting the residue; the solution had always a slightly acid reaction, even as it was obtained after the experiment No. 8 had been made, that is to say, after it had been washed with a large quantity of water.

The first eight experiments were made with $SrSO_4$, obtained from analyses Nos. 1 to 4 of series 1; experiments 9, 10 and 11 with that obtained from analyses Nos. 1 to 4 of series 5; experiments 12 and 13 were made, the former with $SrSO_4$, obtained from analyses Nos. 5 and 6 of series 5, the latter with material freshly precipitated in the cold without alcohol, washed with cold water and without ignition.

1. $SrSO_4$ was boiled with water, and after cooling for twenty-four hours filtered and evaporated:

   500 c.c. = 0.0593 gr. $SrSO_4$
   1 $SrSO_4$ soluble in 8432 water.

2. The residue from 1 was treated again in the same way:

   500 c.c. = 0.0591 gr. $SrSO_4$
   1 $SrSO_4$ soluble in 8460 water.

3. The residue from 2 was treated again in the same way:

   500 c.c. = 0.0601 gr. $SrSO_4$
   1 $SrSO_4$ soluble in 8319 water.

4. The residue from 3 was boiled with water, filtered boiling hot, and after standing for twenty-four hours measured and evaporated:

   500 c.c. = 0.0486 gr. $SrSO_4$
   1 $SrSO_4$ soluble in 10288 water.

5. The residue from 4 was digested for six days with cold water, filtered and evaporated:

   500 c.c. = 0.0642 gr. $SrSO_4$
   1 $SrSO_4$ soluble in 7788 water.

6. The residue from 5 was treated again in the same way:

500 c.c. = 0.0649 gr. $SrSO_4$

1 $SrSO_4$ soluble in 7704 water.

7. The residue from 6 was boiled once more, filtered boiling hot, and after standing for twenty-four hours measured off and evaporated:

500 c.c. = 0.0499 gr. $SrSO_4$

1 $SrSO_4$ soluble in 10020 water.

8. The residue was again digested for six days with cold water, filtered and evaporated:

500 c.c. = 0.0665 gr. $SrSO_4$

1 $SrSO_4$ soluble in 7519 water.

Another portion of this solution was weighed in a 100 gr. flask, containing at 23° C 99.9205 gr. water; it weighed 99.9567 gr., giving the solution a sp. gr. of 1.0004; this would correspond to a solubility of 1:2760, if there had been no condensation; sp. gr. of this precipitate after drying but still containing 0.73 p. c. of water = 3.8681 or without water = 3.9514. See further on.

The solubility of strontium sulphate in water increases by continued digestion with it, as noticed already in the case of barium compounds. It is also less soluble in hot than in cold water, the experiments 1 to 3 standing between, because the hot solution was allowed to remain in contact with the precipitate for twenty-four hours.

9. $SrSo_4$ digested with cold water for six days:

500 c.c. = 0.0638 gr. $SrSO_4$

1 $SrSO_4$ soluble in 7837 water.

10. This treatment repeated with the residue:

500 c.c. = 0.0638 gr. $SrSo_4$

1 $SrSO_4$ soluble in 7837 water.

11. The residue from 10 boiled and filtered boiling hot; after cooling measured and evaporated:

500 c. c. = 0.0496 gr. $SrSO_4$

1 $SrSO_4$ soluble in 10081 water.

12. $SrSO_4$, obtained from a strongly acid solution (Nos. 5 and 6, series 5), digested for four days with cold water:

500 c.c. = 0.0591 gr. $SrSO_4$

1 $SrSO_4$ soluble in 8460 water.

13. $SrSO_4$, precipitated in the cold and not ignited, gave by digestion for six days with cold water in

500 c.c. = 0.0591 gr. $SrSO_4$

1 $SrSO_4$ soluble in 8460 water.

A portion of this solution gave by weighing a sp. gr. of 1.0003, indicating a solubility of 1 : 3122, provided there was no condensation. The precipitate had a sp. gr. of 3.9702.

It will be seen that freshly precipitated strontium sulphate is less soluble than the ignited precipitate; it is also heavier than it, but changes in both particulars by repeated digestion with water. Expressing the solubility of strontium sulphate in water in round numbers I would place it as 1 in 10100 at 100° C, and at 1 in 7700 at 20° C.

To the solutions, as obtained under 12, an equal volume of alcohol was added, and the mixture after stirring allowed to stand for twenty-four hours; after filtering from the slight precipitate that had formed over night, it yielded on evaporation in:

250 c.c. = 0.0055 gr. $SrSO_4$

1 $SrSO_4$ soluble in 45454 alcohol of 45 p.c.

II. Specific gravity of strontium sulphate.[10]

The specific gravities were taken as described under barium, and refer to a temperature of 18° C. unless otherwise stated; they depend, as already pointed out, on the manner in which the substance

[10] Compare: Constants of Nature, Smithsonian Miscellaneous Collections, Part I. page 73, and First Supplement to Part I. page 16; greatest sp. gr. of celestite given is 3.973, of precipitated strontium sulphate 3.770, of artificially crystallized 3.927.

has been obtained, and on the processes to which, after formation it has been subjected; it becomes lighter by ignition and by repeated digestion with water, though if the ignited precipitate be subjected to repeated digestion it becomes heavier, but never as heavy as the precipitated material, which has not been ignited; in the first case, the occluded water, which is in a state of condensation, and which cannot be volatilized by a temperature of 100° C., leaves intermolecular spaces by removal through heat, that are too small for the molecules of water to enter again; there is therefore decrease of weight without change of volume, indicated by lighter specific gravity. In the second case, the groups of molecules break up into groups of fewer members,[11] producing besides decrease of specific gravity more points of attack to water, and consequently increase of solubility. In the third case, where there is increase of solubility and of specific gravity, the water is simply taken up again while the molecular groups are broken up.

1. 5.6191 gr. $SrSO_4$, before the experiments on solubility were made, and right after ignition, had a sp. gr. of 3.6679.

2. 5.1307 gr. $SrSO_4$ the previous material, but after the first eight experiments on solubility had been made with it, and after it had been dried for three hours at 100° C., had a sp. gr. of 3.8681. It contained still 0.73 p. c. of water, which by deduction would give a sp. gr. of 3.9514.

3. 5.0354 gr. $SrSO_4$, obtained from analyses Nos. 1 to 4 of series 5, had immediately after ignition a sp. gr. of 3.6949.

4. 2.5739 gr. $SrSO_4$, precipitated from a solution of strontium chloride by dilute sulphuric acid in the cold, and washed without the addition of alcohol with distilled water, gave a sp. gr. as described in Part I, p. 18, of 3.9702.

5. 4.6085 gr. $SrSO_4$, obtained as under 4, except that the solution was boiling hot, gave a sp. gr. of 3.9502.

6. The two previous precipitates were united, boiled with water, filtered and dried for three hours at 100° C. 5.6565 gr. gave a sp. gr. of 3.7260, and as it still contained 0.12 p. c. of water, by deduction a sp. gr. of 3.7383.

[11] See Part I, pp. 2 and 18.

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PERMANENT

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A Modification of Wenham's Reflex Illuminator. By R. H. Ward, of Troy, N. Y.

[ABSTRACT.]

Mr. Wenham's reflex illuminator was designed to avoid direct illumination, by passing light into the slide at such an angle that it would be totally reflected instead of passing into air above the slide. With dry mounted objects, or with dry objectives of any angle, this illumination would be exclusively reflex, since no light could pass directly to the objective; and with immersion objectives of angular aperture not greater than that corresponding to 180 degrees dry, the result would be practically the same, as the light, after passing through a balsam mounted object, would reach the lens at an obliquity greater than that of its extreme capacity for image-forming rays. But for lenses of greater angle than this, the illumination would be direct, the image being formed by that portion of the available aperture of the lens which was in excess of the equivalent of 180 degrees dry angle. The existence and even the possibility of such lenses were not at that time undisputed, some eminent microscopists still maintaining the contrary opinion. Soon after the reflex illuminator had arrived in this country, Mr. Samuel Wells, of Boston, succeeded with ease in making it act as a direct illuminator, with lenses of more than one maker, an excellent and serviceable image being formed by these extralimital rays. The same lenses, at least those of one of the makers, had previously been made to give, by means of a semi-cylinder of glass (including the thickness of the glass slide) with an adjustable shutter, a well defined image formed of similar extralimital rays. Mr. Wells' experiments immediately led Mr. R. B. Tolles, of Boston, to make a variety of such prisms with the angle of the reflecting face changed so that the illuminating pencil should fall within instead of just beyond the angle of total reflection. Several of these were made of various angles, but, in the expectation of making further improvement in the plan, they were kept in the maker's hands. One now shown has an angle of 14 degrees, and is suitable for lenses of small angle. Another has its face inclined at an angle of 21 degrees, giving an obliquity of 42 degrees to the central reflected ray. This utilizes the extreme angle of an objective up to 180 degrees dry, or its equivalent in

balsam, and in addition gives a slight illumination by admission of extralimital rays available exclusively to immersion lenses of excessive aperture. With suitable lenses it gives prompt resolution of numbers eighteen, nineteen, and twenty of Moller's test plate in balsam by lamplight. It gives their maximum efficiency with dry mounts and with dry lenses, as the extreme capacity of the lens is utilized by the half pencil from the illuminator which can be transmitted to it, a condition very favorable for resolution of difficult objects. As in the original reflex, the chromatic aberration is excessive; and it is a question how far the very decided results attained in resolution are due to the nearly perfect monochromatic illumination thus secured. The modified prisms are inferior to the original for use with lenses capable of taking up half the pencil transmitted into balsam by the original reflex. They do not seem to have given results not otherwise attainable, and they are subject to the inconvenience that each one is limited to a fixed and comparatively narrow range of angles; but they furnish a ready and easy means of oblique illumination, suitable for extremely difficult resolution, and entirely independent of thinness of stage and concentric rotation of object-carrier.

TITLES OF OTHER PAPERS READ IN SUBSECTION OF MICROSCOPY.

A new Periscopic Eye-piece. By Ernst Gundlach, of Rochester, N. Y.

On the Cellular Structure of Dentine. By R. H. Ward, of Troy, N. Y.

On the use of Ordinary Low Power Objectives for Photography. By C. Leo Mees, of Louisville, Ky.

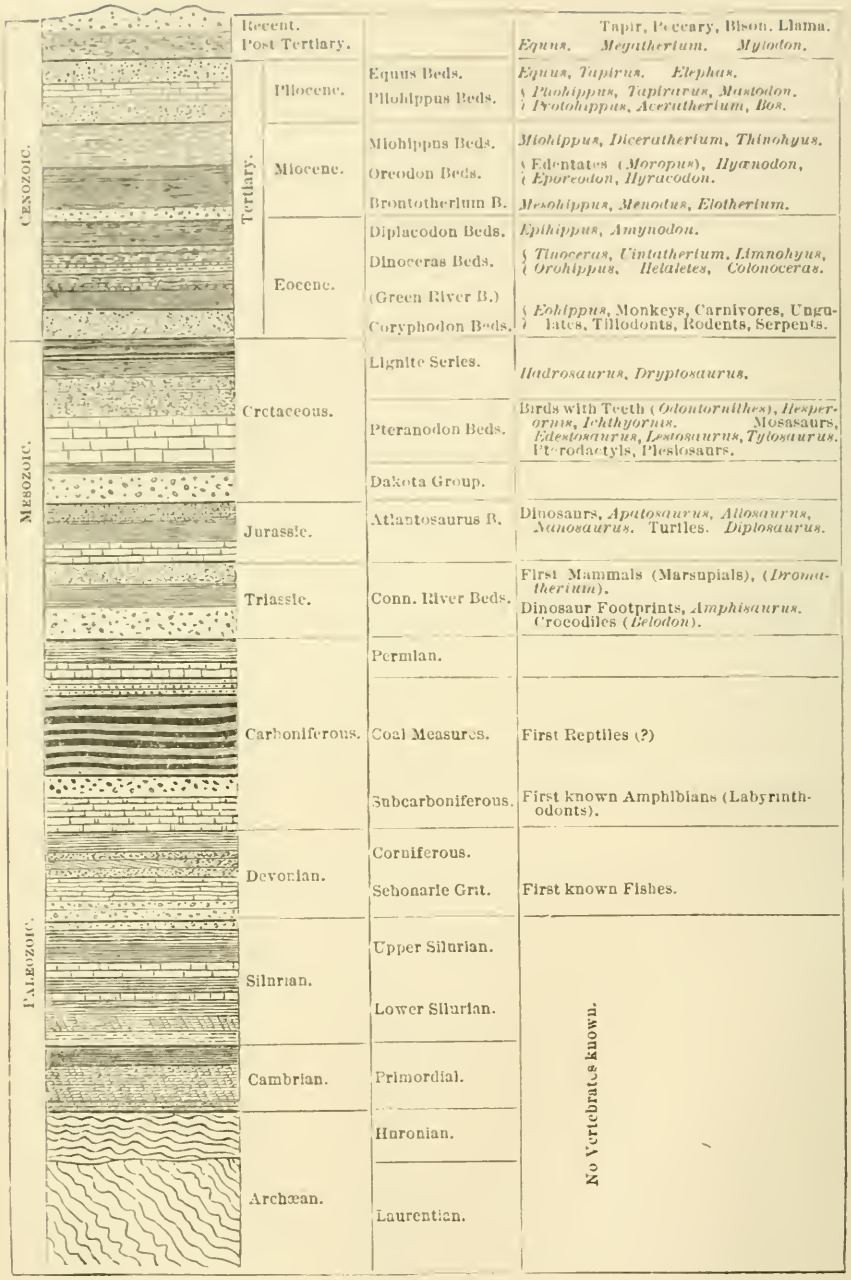
On Accessories adapted to Lithological Investigation. By Alexis A. Julien, of New York.

On Objectives as Illuminators. By George W. Morehouse, of Wayland, N. Y.

On the Relative Value of the Powers of Objectives and Eye-pieces. By T. O. Sumners, Jr., of Nashville, Tenn.

SECTION B.

NATURAL HISTORY.



SECTION OF THE EARTH'S CRUST.

TO ILLUSTRATE VERTEBRATE LIFE IN AMERICA.

ADDRESS

OF

PROFESSOR O. C. MARSH,

VICE PRESIDENT, SECTION B.

Members of the Association:—

Ladies and Gentlemen:—

The origin of life, and the order of succession in which its various forms have appeared upon the earth, offer to science its most inviting and most difficult field of research. Although the primal origin of life is unknown, and may perhaps never be known, yet no one has a right to say how much of the mystery now surrounding it science cannot remove. It is certainly within the domain of science to determine when the earth was first fitted to receive life, and in what form the earliest life began. To trace that life in its manifold changes through past ages to the present is a more difficult task, but one from which modern science does not shrink. In this wide field every earnest effort will meet some degree of success; every year will add new and important facts; and every generation will bring to light some law, in accordance with which ancient life has been changed into life as we see it around us to-day. That such a development has taken place, no one will doubt who has carefully traced any single group of animals through its past history, as recorded in the crust of the earth. The evidence will be especially conclusive, if the group

selected belongs to the higher forms of life, which are sensitive to every change in their surroundings. But I am sure I need offer here no argument for evolution; since to doubt evolution to-day is to doubt science, and science is only another name for truth.

Taking, then, evolution as a key to the mysteries of past life on the earth, I invite your attention to the subject I have chosen: The Introduction and Succession of Vertebrate Life in America.

In the brief hour allotted to me, I could hardly hope to give more than a very incomplete sketch of what is now known on this subject. I shall, therefore, pass rapidly over the lower groups, and speak more particularly of the higher vertebrates, which have an especial interest to us all, in so far as they approach man in structure, and thus indicate his probable origin. These higher vertebrates, moreover, are most important witnesses of the past, since their superior organization made them ready victims to slight climatic changes, which would otherwise have remained unrecorded.

In considering the ancient life of America, it is important to bear in mind that I can only offer you a brief record of a few of the countless forms that once occupied this continent. The review I can bring before you will not be like that of a great army, when regiment after regiment with full ranks moves by in orderly succession, until the entire host has passed. My review must be more like the roll-call after a battle, when only a few scarred and crippled veterans remain to answer to their names. Or rather, it must resemble an array of relics dug from the field of some old Trojan combat, long after the contest, when no survivor remains to tell the tale of the strife. From such an ancient battle-field, a Schliemann might unearth together the bronze shield, lance-head, and gilded helmet of a prehistoric leader, and learn from them with certainty his race and rank. Perhaps the skull might still retain the barbaric stone weapon by which his northern foe had slain him. Near by, the explorer might bring to light the commingled coat of mail and trappings of a horse and rider, so strangely different from the equipment of the chief as to suggest a foreign ally. From these, and from the more common implements of war that fill the soil, the antiquary could determine, by patient study, what nations fought, and, perhaps, when, and why.

By this same method of research, the more ancient strata of the

earth have been explored, and, in our Western wilds, veritable battle-fields, strewn with the fossil skeletons of the slain, and guarded faithfully by savage superstition, have been despoiled, yielding to science treasures more rare than bronze or gold. Without such spoils from many fields, I could not have chosen the present theme for my address to-night.

According to present knowledge, no vertebrate life is known to have existed on this continent in the Archæan, Cambrian, or Silurian periods; yet during this time more than half of the thickness of American stratified rocks was deposited. It by no means follows that vertebrate animals of some kind did not exist here in those remote ages. Fishes are known from the Upper Silurian of Europe, and there is every probability that they will yet be discovered in our strata of the same age, if not at a still lower horizon.

In the shore deposits of the early Devonian sea, known as the Schoharie Grit, characteristic remains of Fishes were preserved, and in the deeper sea that followed, in which the Corniferous limestone was laid down, this class was well represented. During the remainder of the Devonian, Fishes continue abundant in the shallower seas, and, so far as now known, were the only type of vertebrate life. These Fishes were mainly Ganoids, a group represented in our present waters by the Gar-pike (*Lepidosteus*) and Sturgeon (*Acipenser*), but in the Devonian sea, chiefly by the Placoderms, the exact affinities of which are somewhat in doubt. With these were Elasmobranchs, or the Shark tribe, and among them a few Chimæroids, a peculiar type, of which one or two members still survive. The Placoderms were the monarchs of the ocean. All were well protected by a massive coat of armor, and some of them attained huge dimensions. The American Devonian fishes now known are not as numerous as those of Europe, but they were larger in size, and mostly inhabitants of the open sea. Some twenty genera and forty species have been described.

The more important genera of Placoderms are *Dinichthys*, *Aspidichthys*, and *Diplognathus*, our largest Palæozoic fishes. Others are, *Acanthaspis*, *Acantholepis*, *Coccosteus*, *Macropetalichthys*, and *Onychodus*. Among the Elasmobranchs were *Cladodus*, *Ctenacanthus*, *Machæracanthus*, *Rhynchodus*, and *Ptyctodus*, the last two being regarded as Chimæroids. In the Chemung epoch,

the great Dipterian family was introduced with *Dipterus*, *Heliodus*, and possibly *Ceratodus*. Species of the European genera, *Bothriolepis*, and *Holoptychius*, have likewise been found in our Devonian deposits.

With the close of the Devonian, came the almost total extinction of the great group of Placoderms, while the Elasmobranchs, which had hitherto occupied a subordinate position, increase in numbers and size, and appear to be represented by Sharks, Rays, and Chimæras. Among the members of this group from the Carboniferous, were numerous Cestracionts, species of *Cochliodus* of large size, with others of the genera *Deltodus*, *Helodus*, *Psammodus* and *Sandalodus*. Of the Petalodonts, there were *Antliodus*, *Chomatodus*, *Ctenoptychius*, *Petalodus*, and *Petalorhynchus;* and of the Hybodonts, the genera *Cladodus*, *Carcharopsis* and *Diplodus*. These Elasmobranchs were the rulers of the Carboniferous open sea, and more than one hundred species have been found in the lower part of this formation alone. The Ganoids, although still abundant, were of smaller size, and denizens of the more shallow and confined waters. The latter group of fishes was represented by true Lepidostidæ, of the genera *Palæoniscus*, *Amblypterus*, *Platysomus* and *Eurylepis*. Other genera are *Rhizodus*, *Megalichthys*, *Ctenodus*, *Edestus*, *Orodus*, *Ctenacanthus*, *Gyracanthus*, and *Cœlacanthus*. Most of these genera occur also in Europe.

From the Permian rocks of America, no vertebrate remains are known, although in the same formation of Europe Ganoids are abundant; and with them are remains of Sharks, and some other fishes, the affinities of which are doubtful. The Palæozoic fishes at present known from this country are quite as numerous as those found in Europe.

In the Mesozoic age, the Fishes of America begin to show a decided approach to those of our present waters. From the Triassic rocks, Ganoids only are known, and they are all more or less closely related to the modern Gar-pike or *Lepidosteus*. They are of small size, and the number of individuals preserved is very large. The characteristic genera are, *Catopterus*, *Ischypterus*, *Ptycholepis*, *Rhabdolepis*, and *Turseodus*. From the Jurassic deposits, no remains of fishes are known,[1] but in the Cretaceous, ichthyic life assumed many and various forms; and the first

[1] A species of *Ceratodus* has recently been found in the upper Jurassic of Colorado, and named by the writer *C. Günthert.* — O. C. M.

representatives of the Teleosts, or bony fishes, the characteristic fishes of to-day, make their appearance. In the deep open sea of this age, Elasmobranchs were the prevailing forms, Sharks and Chimæroids being most numerous. In the great inland Cretaceous sea of North America, true osseous fishes were most abundant, and among them were some of carnivorous habits and immense size. The more sheltered bays and rivers were shared by the Ganoids and Teleosts, as their remains testify. The more common genera of Cretaceous Elasmobranchs were *Otodus*, *Oxyrhina*, *Galeocerdo*, *Lamna* and *Ptychodus*. Among the osseous fishes, *Beryx*, *Enchodus*, *Portheus* and *Saurocephalus* were especially common, while the most important genus of Ganoids was *Lepidotus*.

The Tertiary fishes are nearly all of modern types, and from the beginning of this period there was comparatively little change. In the marine beds, Sharks, Rays and Chimæroids maintained their supremacy, although Teleosts were abundant, and many of them of large size. The Ganoids were comparatively few in number. In the earliest Eocene fresh-water deposits, it is interesting to find that the modern Gar-pike, and *Amia*, the Dog-fish of our western lakes, which by their structure are seen to be remnants of a very early type, are well represented by species so closely allied to them that only an anatomist could separate the ancient from the modern. In the succeeding beds, these fishes are still abundant, and with them are Siluroids nearly related to the modern Cat-fish (*Pimelodus*). Many small fishes, allied apparently to the modern herring (*Clupea*), left their remains in great numbers in the same deposits, and, with them has been recently found a land-locked Ray (*Heliobatis*).

The almost total absence of remains of fishes from the Miocene lake basins of the West is a remarkable fact, and perhaps may best be explained by the theory that these inland waters, like many of the smaller lakes in the same region to-day, were so impregnated with mineral matters as to render the existence of vertebrate life in them impossible. No one who has tasted such waters, or has attempted to ford one of the modern alkaline lakes which are often met with on the present surface of the same deposits, will doubt the efficiency of this cause, or the easy entombment of the higher vertebrates that ventured within their borders. In the Pliocene lake-basins of the same region, remains of fishes were not uncommon, and in some of them are very numerous. These are all of

modern types, and most of them are Cyprinoids, related to the modern Carp. The Post-pliocene fishes are essentially those of to-day.

In this brief synopsis of the past ichthyic life of this Continent, I have mentioned only a few of the more important facts, but sufficient, I trust, to give an outline of its history. Of this history, it is evident that we have as yet only a very imperfect record. We have seen that the earliest remains of fishes known in this country are from the lower Devonian; but these old fishes show so great a diversity of form and structure, as to clearly indicate for the class a much earlier origin. In this connection, we must bear in mind that the two lowest groups of existing fishes are entirely without osseous skeletons, and hence, however abundant, would leave no permanent record in the deposits in which remains of fishes are usually preserved. It is safe to infer, from the knowledge which we now possess of the simpler forms of life, that even more of the early fishes were cartilaginous, or so destitute of hard parts as to leave no enduring traces of their existence. Without positive knowledge of such forms, and considering the great diversity of those we have, it would seem a hopeless task at present to attempt to trace successfully the genealogy of this class. One line, however, appears to be direct, from our modern Gar-pike, through the lower Eocene *Lepidosteus* to the *Lepidotus* of the Cretaceous, and perhaps on through the Triassic *Ischypterus* and Carboniferous *Palæoniscus;* but beyond this, in our rocks, it is lost. The living Chimæra of our Pacific coast has nearly allied forms in the Tertiary and Cretaceous, more distant relatives in the Carboniferous, and a possible ancestor in the Devonian *Rhynchodus.* Our Sharks likewise can be traced with some certainty back to the Palæozoic; and even the *Lepidosiren*, of South America, although its immediate predecessors are unknown, has some peculiar characters which strongly point to a Devonian ancestry. These suggestive lines indicate a rich field for investigation in the ancient life-history of American fishes.

The Amphibians, the next higher class of vertebrates, are so closely related to the fishes in structure, that some peculiar forms of the latter have been considered by anatomists as belonging to this group. The earliest existence of Amphibian evidence, on this continent, is in the Sub-Carboniferous, where foot-prints have been

found which were probably made by Labyrinthodonts, the most ancient representatives of the class. Well preserved remains are abundant in the Coal Measures, and show that the Labyrinthodonts differed in important particulars from all modern Amphibians, the group which includes our frogs and salamanders. Some of these ancient animals resembled a salamander in shape, while others were serpent-like in form. None of those yet discovered were frog-like, or without a tail, although the restored Labyrinthodont of the text books is thus represented. All were protected by large pectoral bony plates, and an armor of small scutes on the ventral surface of the body. The walls of the teeth were more or less folded, whence the name Labyrinthodont. The American Amphibians known from osseous remains are all of moderate size, but the foot-prints attributed to this group indicate animals larger than any of the class yet found in the old world. The Carboniferous Amphibians were abundant in the swampy tropical forests of that period, and their remains have been found imbedded in the coal then deposited, as well as in hollow stumps of the trees left standing.

The principal genera of this group from American Carboniferous rocks, are, *Sauropus*, known only from foot-prints, *Baphetes*, *Dendrerpeton*, *Hylonomus*, *Hylerpeton*, *Raniceps*, *Pelion*, *Leptophractus*, *Molgophis*, *Ptyonius*, *Amphibamus*, *Cocytinus*, and *Ceraterpeton*. The last genus occurs also in Europe. Certain of these genera have been considered by some writers to be more nearly related to the Lizards, among true reptiles. Some other genera known from fragmentary remains or foot-prints in this formation have likewise been referred to the true reptiles, but this question can perhaps be settled only by future discoveries.

No Amphibia are known from American Permian strata, but in the Triassic, a few characteristic remains have been found. The three genera, *Dictyocephalus*, *Dispelor* and *Pariostegus*, have been described, but, although apparently all Labyrinthodonts, the remains preserved are not sufficient to add much to our knowledge of the group. The Triassic foot-prints which have been attributed to Amphibians are still more unsatisfactory, and at present no important conclusions in regard to this class can be based upon them. From the Jurassic and Cretaceous beds of this Continent, no remains of Amphibians are known. A few only have been found in the Tertiary, and these are all of modern types.

The Amphibia are so nearly allied to the Ganoid fishes that we can hardly doubt their descent from some member of that group. With our present limited knowledge of the extinct forms, however, it would be unprofitable to attempt to trace in detail their probable genealogy.

The authors to whom especial credit is due for our knowledge of American fossil Fishes and Amphibians are Newberry, Leidy, Cope, Dawson, Agassiz, St. John, Gibbes, Wyman, Redfield, and Emmons, and the principal literature of the subject will be found in their publications.

Reptiles and Birds form the next great division of vertebrates, the Sauropsida, and of these the Reptiles are the older type, and may be first considered. While it may be stated with certainty that there is at present no evidence of the existence of this group in American rocks older than the Carboniferous there is some doubt in regard to their appearance even in this period. Various foot-prints which strongly resemble those made by Lizards; a few well preserved remains similar to the corresponding bones in that group; and a few characteristic specimens, nearly identical with those from another order of this class, are known from American Coal Measures. These facts, and some others which point in the same direction, render it probable that we may soon have conclusive evidence of the presence of true Reptiles in this formation, and in our overlying Permian, which is essentially a part of the same series. In the Permian rocks of Europe, true Reptiles have been found.

The Mesozoic Period has been called the Age of Reptiles, and during its continuance some of the strangest forms of reptilian life made their appearance, and became extinct. Near its commencement, while the Triassic shales and sandstones were being deposited, true reptiles were abundant. Among the most characteristic remains discovered are those of the genus *Belodon*, which is well known also in the Trias of Europe. It belongs to the Thecodont division of Reptiles, which have teeth in distinct sockets, and its nearest affinities are with the *Crocodilia*, of which order it may be considered the oldest known representative. In the same strata in which the Belodonts occur, remains of Dinosaurs are found, and it is a most interesting fact that these highest of reptiles should make their appearance, even in a generalized form,

at this stage of the earth's history. The Dinosaurs, although true reptiles in all their more important characters, show certain well marked points of resemblance to existing birds of the order *Ratitæ*, a group which includes the Ostriches; and it is not improbable that they were the parent stock from which birds originated.

During Triassic time the Dinosaurs attained in America an enormous development both in variety of forms and in size. Although comparatively few of their bones have as yet been discovered in the rocks of this country, they have left unmistakable evidence of their presence in the foot-prints and other impressions upon the shores of the waters which they frequented. The Triassic sandstone of the Connecticut Valley has long been famous for its fossil foot-prints, especially the so-called "bird-tracks," which are generally supposed to have been made by birds, the tracks of which many of them closely resemble. A careful investigation, however, of nearly all the specimens yet discovered, has convinced me that there is not a particle of evidence that any of these fossil impressions were made by birds. Most of these three-toed tracks were certainly not made by birds; but by quadrupeds, which usually walked upon their hind feet alone, and only occasionally put to the ground their smaller anterior extremities. I have myself detected the impressions of these anterior limbs in connection with the posterior foot-prints of nearly all of the supposed "bird-tracks" described, and have little doubt that they will eventually be found with all. These double impressions are precisely the kind which Dinosaurian reptiles would make, and as the only characteristic bones yet found in the same rocks belong to animals of this group, it is but fair to attribute all these foot-prints to Dinosaurs, even where no impressions of fore-feet have been detected, until some evidence appears that they were made by Birds. I have no doubt that Birds existed at this time, although at present the proof is wanting.

The principal genera of Triassic Reptiles known from osseous remains in this country are, *Amphisaurus* (*Megadactylus*), from the Connecticut Valley, *Bathygnathus*, from Prince Edward's Island, *Belodon* and *Clepsysaurus*. Other generic names which have been applied to foot-prints and to fragmentary remains need not be here enumerated. A few remains of Reptiles have been found in undoubted Jurassic rocks of America, but they are not

sufficiently well determined to be of service in this connection.[2] Others have been reported from supposed Jurassic strata, which are now known to be Cretaceous. It will thus be seen that although reptilian life was especially abundant during the Triassic and Jurassic periods, but few bones have been found. This is owing in part to the character of most of the rocks then formed which were not well fitted for preserving such remains, although admirably adapted to retain foot-prints.

During the Cretaceous Period, Reptilian life in America attained its greatest development, and the sediments laid down in the open seas and estuaries were usually most favorable for the preservation of a faithful record of its various phases. Without such a perfect matrix as some of these deposits afford, many of the most interesting vertebrates recently brought to light from this formation would probably have remained unknown. The vast extent of these beds ensures, moreover, many future discoveries of interest.

In the lowest Cretaceous strata of the Rocky Mountain region, the Dakota group, part of which at least represents the Wealden of Europe, remains of *Chelonia*, or Turtles, Crocodiles and Dinosaurs occur, the last being especially abundant. The *Chelonia*, although known from the Jurassic of Europe, here appear for the first time in American rocks. Some of the earliest forms are allied to the modern genus *Trionyx*. In the higher Cretaceous beds, some Chelonians of enormous size have been found. They belong to the genus *Atlantochelys*, which has the ribs separate, as in the existing *Sphargis*, and presents other embryonic characters. A few genera appear to be related to the modern genus *Chelone*. The remaining Cretaceous species were mostly of the Emydoid type; and others were related to *Chelydra*. The more important genera of Cretaceous Chelonians known from characteristic specimens are, *Atlantochelys* (*Protostega*), *Adocus*, *Bothremys*, *Compsemys*, *Plastomenus*, *Osteopygis*, *Propleura*, *Lytoloma* and *Taphrosphys*. Most of these genera were represented by several species, and the individuals were numerous. No land Tortoises have as yet been found in this formation. In American Tertiary deposits, Chelonians are abundant, especially in the fresh-water beds. They all show near affinities with modern types, and most of them can

[2] Since this address was delivered, I have determined the beds containing gigantic Dinosaurs, on the flanks of the Rocky Mountains, to be upper Jurassic, and called them Atlantosaurus beds. (See frontispiece, section.) These strata were formerly referred to the Dakota group, or base of the Cretaceous.—O. C. M.

be referred to existing genera. In the Tertiary lake-basins of the West, land Tortoises are very numerous, and with them are many fresh-water forms of *Trionyx* and allied genera.

A striking feature of the American Cretaceous fauna, as contrasted with that of Europe, is the almost entire absence in our strata of species of *Ichthyosaurus* and *Plesiosaurus*, which abound in many other regions, but here seem to be replaced by the Mosasaurs. A few fragmentary remains have indeed been referred to these genera, but the determination may fairly be questioned. This is more than true of the proposed new order *Streptosauria*, which was founded wholly on error. The order *Plesiosauria*, however, is well represented, but mainly by forms more nearly related to the genus *Pliosaurus* than to the type of the group. These were marine reptiles, all of large size, while some of them attained vast dimensions. So far as at present identified, they may be referred to the genera, *Cimoliosaurus*, *Discosaurus* (*Elasmosaurus*), and *Pliosaurus*. The number of species is comparatively few, and none are known above the Cretaceous. The important suggestion of Gegenbaur, that the *Halisauria*, which include the Plesiosaurs, branched off from the Fishes before the Amphibians, finds some support in American specimens recently discovered.

The Reptiles most characteristic of our American Cretaceous strata are the *Mosasauria*, a group with very few representatives in other parts of the world. In our Cretaceous seas, they ruled supreme, as their numbers, size, and carnivorous habits enabled them to easily vanquish all rivals. Some were at least sixty feet in length, and the smallest ten or twelve. In the inland Cretaceous sea from which the Rocky Mountains were beginning to emerge, these ancient "Sea Serpents" abounded; and many were entombed in its muddy bottom. On one occasion, as I rode through a valley washed out of this old ocean bed, I saw no less than seven different skeletons of these monsters in sight at once. The Mosasaurs were essentially swimming Lizards, with four well developed paddles, and they had little affinity with modern serpents, to which they have been compared. The species are quite numerous, but they belong to comparatively few genera, of which *Mosasaurus*, *Tylosaurus*, *Lestosaurus*, *Edestosaurus*, have alone been identified with certainty. The genus *Mosasaurus* was first found in Europe. All the known species of the group are Cretaceous.

The *Crocodilia* are abundant in rocks of Cretaceous age in America, and two distinct types are represented. The older type, which is foreshadowed by *Belodon* of the Trias, has biconcave vertebræ, and shows marked affinities with the genus *Teleosaurus*, from the Jura of Europe. The best known genus is *Hyposaurus*, of which there are several species, all more or less resembling in form the modern Gavial, of the Ganges. A peculiar intermediate form is seen in *Diplosaurus*, from the Wealden of the Rocky Mountains. The second type, which now makes its appearance for the first time, has procœlian vertebræ, and in other respects resembles existing Crocodiles. The genera described are *Bottosaurus*, *Holops* and *Thoracosaurus*, none of which, so far as known, pass above the Cretaceous. Of *Crocodilia* with opisthocœlous vertebræ, America, so far as we know, has none. Specimens similar to those so termed in Europe, are not uncommon here, but they pertain to Dinosaurs.

In the Eocene fresh-water beds of the West, Crocodilians are especially abundant, and all, with the exception of *Limnosaurus*, belong apparently to the genus *Crocodilus*, although some species show certain points of resemblance to existing Alligators. The Miocene lake-basins of the same region contain no remains of Crocodiles, so far as known, and the Pliocene deposits have afforded only a single species. The Tertiary marine beds of the Atlantic Coast contain comparatively few Crocodilian remains, and all are of modern types; the genus *Gavialis* having one Eocene species, and the Alligator being represented only in the latest deposits.

It is worthy of special mention in this connection, that no true *Lacertilia*, or Lizards, and no *Ophidia*, or Serpents, have yet been detected in American Cretaceous beds; although their remains, if present, would hardly have escaped observation in the regions explored. The former will doubtless be found, as several species occur in the Mesozoic of Europe; and perhaps the latter, although the Ophidians are apparently a more modern type. In the Eocene lake-basins of Western America, remains of Lizards are very numerous, and indicate species much larger than any existing to-day. Some of these, the *Glyptosauridæ*, were protected by a highly ornamented bony coat of mail, and others were covered with scales, like recent Lizards. A few resembled, in their more important characters, the modern Iguana. The genera best represented in

the Eocene are, *Glyptosaurus*, *Iguanacus*, *Oreosaurus*, *Thinosaurus*, *Tinosaurus* and *Sauiva*. Some of these genera appear to have continued into the Miocene, but here, as well as in the Pliocene, few remains of this group have been found. It is not improbable that some of our extinct Reptiles may prove to belong to *Rynchocephala*, but at present this is uncertain. The genus *Notosaurus*, from Brazil, has biconcave vertebræ, and some other characters which point to that group. No Dicynodonts or Theriodonts have as yet been found in this country.

The first American Serpents, so far as now known, appear in the Eocene, which contains also the oldest European species. On the Atlantic border, the genus *Titanophis* (*Dinophis*) is represented by several species of large size, one at least thirty feet in length, and all doubtless inhabitants of the sea. In the fresh-water Western Eocene, remains of snakes are abundant, but all are of moderate size. The largest of these were related to the modern Boa Constrictors. The genera described are *Boavus*, *Lithophis*, and *Limnophis*. The Miocene and Pliocene Snakes from the same region are known only from a few fragmentary remains.

The *Pterosauria*, or flying Lizards, are among the most interesting Reptiles of Mesozoic time, and many of them left their remains in the soft sediments of our inland Cretaceous sea. These were veritable Dragons, having a spread of wings of from ten to twenty-five feet. They differed essentially from the smaller Pterodactyles found in the old world, in the entire absence of teeth, showing in this respect a resemblance to modern birds; and they possess other distinctive characters. They have, therefore, been placed in a new order, *Pteranodontia*, from the typical genus *Pteranodon*, of which five species are known. The only other genus is *Nyctosaurus*, represented by a single species. All the specimens yet found are from essentially the same horizon, in the Chalk of Kansas. The reported discovery of remains of this order from older formations in this country is without foundation.

The strange Reptiles known as *Dinosauria*, which, as we have seen, were numerous during the deposition of our Triassic shales and sandstones, have not yet been found in American Jurassic,[3] but were well represented here throughout the Cretaceous, and at its close became extinct. These animals possess a peculiar interest to the anatomist, since, although reptilian in all their main

[3] See note on page 220.

characters, they show clear affinities with the Birds, and have some features which may point to Mammals. The Cretaceous Dinosaurs were all of large size, and most of them walked on the hind feet alone, like modern Struthious birds. Two well marked types may be distinguished among the remains discovered in deposits of this age: the herbivorous forms, represented mainly by *Hadrosaurus*, a near ally of the *Iguanodon* of Europe; and their carnivorous enemies, of which *Dryptosaurus* (*Laelaps*) may be considered typical in this country, and *Megalosaurus* in Europe. Near the base of our Cretaceous formation, in beds which I regard as the equivalent of the European Wealden, the most gigantic forms of this order yet discovered have recently been brought to light. One of these monsters (*Titanosaurus montanus*),[4] from Colorado, is by far the largest land animal yet discovered; its dimensions being greater than was supposed possible, in an animal that lived and moved upon the land. It was some fifty or sixty feet in length, and, when erect, at least thirty feet in height. It doubtless fed upon the foliage of the mountain forests, portions of which are preserved with its remains. With *Titanosaurus*, the bones of smaller Dinosaurs, one (*Nanosaurus*) not larger than a Cat, as well as those of Crocodiles and turtles, are not uncommon.[5] The recent discovery of these interesting remains, many and various, in strata that had long been pronounced by professional explorers barren of vertebrate fossils, should teach caution to those who decline to accept the imperfection of our knowledge to-day as a fair plea for the supposed absence of intermediate forms.

In the marine Cretaceous beds of the West, only a single Dinosaur (*Hadrosaurus agilis*) has been found, but in the higher fresh-water beds, which mark the close of this formation, their remains are numerous, and indicate several well marked species, if not genera. In the marine beds on the Atlantic Coast, the bones of Dinosaurs are frequently met with, and in the Upper Cretaceous Greensand of New Jersey, the type specimens of *Hadrosaurus* and *Dryptosaurus* were found. In Cretaceous fresh-water deposits on the coast of Brazil, remains of this order occur, but the speci-

[4] This generic name proved to be preoccupied, and I have substituted for it *Atlantosaurus*.—O. C. M.

[5] A new order of huge reptiles (*Stegosauria*), apparently allied to the Dinosaurs and Chelonia, and several new genera of Dinosaurs (*Allosaurus*, *Apatosaurus*, *Creosaurus*, *Laosaurus*, and *Morosaurus*), have since been described by the writer, from the same upper Jurassic horizon. (American Journal of Science.)

mens hitherto discovered are not sufficiently characteristic for accurate determination. This is unfortunately true of many Dinosaurian fossils from North America, but the great number of these Reptiles which lived here during the Cretaceous Period promises many future discoveries, and substantial additions to our present knowledge of the group.

The first appearance of Birds in America, according to our present knowledge, was during the Cretaceous Period, although many announcements have been made of their existence in preceding epochs. The evidence of their presence in the Trias, based on foot-prints and other impressions, is, at present, as we have seen, without value; although we may confidently await their discovery there, if not in older formations. *Archæopteryx*, from the European Jura, the oldest bird known, and now fortunately represented by more than a single specimen, clearly indicates a much higher antiquity for the class. The earliest American forms, at present known, are the *Odontornithes*, or Birds with teeth, which have been exhumed within the last few years, from the Chalk of Kansas. The two genera, *Hesperornis* and *Ichthyornis*, are types of distinct orders, and differ from each other and from *Archæopteryx* much more than do any existing birds among themselves; thus showing that Birds are now a closed type, and that the key to the history of the class must be sought for in the distant past.

In *Hesperornis*, we have a large aquatic bird, nearly six feet in length, with a strange combination of characters. The jaws were provided with teeth, set in grooves; the wings were rudimentary, and useless; while the legs were very similar to those of modern diving birds. This last feature was merely an adaptation, as the more important characters are Struthious, showing that *Hesperornis* was essentially a carnivorous swimming Ostrich. *Ichthyornis*, a small flying bird, was stranger still, as the teeth were in sockets; and the vertebræ biconcave, as in Fishes, and a few Reptiles. * Apatornis* and other allied forms occur in the same beds, and probably all were provided with teeth. It is strange that the companions of these ancient toothed Birds should have been Pterodactyles without teeth. In the later Cretaceous beds of the Atlantic Coast, various remains of aquatic Birds have been found, but all are apparently distinct from those of the West. The known

genera of American Cretaceous birds are, *Apatornis*, *Baptornis*, *Graculavus*, *Hesperornis*, *Ichthyornis*, *Laornis*, *Lestornis*, *Palæotringa*, and *Telmatornis*. These are represented by some twenty species. In Europe, but two species of Cretaceous birds are known, and both are based upon fragmentary specimens.

During the Tertiary period, Birds were numerous in this country, and all yet discovered appear to have belonged to modern types. The Eocene species described are mostly wading birds, but here, and in the later Tertiary deposits, some characteristic American forms make their appearance, strongly foreshadowing our present avian fauna. The extinct genera are the Eocene *Uintornis*, related to the Woodpeckers, and *Aletornis*, which includes several species of Waders. Among the existing genera found in our Tertiary beds are *Aquila*, *Bubo*, *Meleagris*, *Grus*, *Graculus*, *Puffinus*, *and Catarractes*. The Great Auk (*Alca impennis*), which was once very abundant on our Northeast Coast, has become extinct within a few years.

In this brief summary of the past life of Reptiles and Birds in America, I have endeavored to exclude doubtful forms, and those very imperfectly known, preferring to present the conclusions reached by careful study, incomplete though they be, rather than weary you with a descriptive catalogue of all the fossils to which names have been applied. Even this condensed review can hardly fail to give you some conception of the wealth of our continent in the extinct forms of these groups, and thus to suggest what its actual life must have been.

Although the Trias offers at present the first unquestioned evidence of true Reptiles, we certainly should not be justified in supposing for a moment that older forms did not exist. So too, in considering the different groups of Reptiles which seem to make their first appearance at certain horizons, flourish for a time, and then decline, or disappear, every day brings evidence to show that they are but fragments of the unraveled strands which converge in the past to form the mystic cord uniting all life. If the attempt is made to follow back any single thread, and thus trace the lineage of a group, we are met by difficulties which the science of to-day can only partially remove. And yet the anatomist constantly sees in the fragments which he studies hints of relationship which are to him sure prophecies of future discoveries.

The genealogy of the *Chelonia* is at present unknown, and our

American extinct forms, so far as we now have them, throw little light on their ancestry. This is essentially true, also, of our *Plesiosauria*, *Lacertilia*, and *Ophidia*, although suggestive facts are not wanting to indicate possible lines of descent. With the *Crocodilia*, however, the case seems to be different, and Huxley has already pointed out the path for investigation. It is probable that material already exists in our museums for tracing the group through several important steps in its development. We have already seen that the modern procœlian type of this order goes back only to the Upper Cretaceous, while the Belodonts, of our Triassic rocks, with their biconcave vertebræ, are the oldest known Crocodilians. Our Jurassic, unfortunately, throws but little light on the intermediate forms, but we know that the line was continued, as it was in the old world through *Teleosaurus*. The beds of the Rocky Mountain Wealden[6] have just furnished us with a genuine "missing link," a saurian (*Diplosaurus*) with essentially the skull and teeth of a modern Crocodile, and the vertebræ of its predecessor from the Trias. This peculiar reptile clearly represents an important stage in the progressive series, and evidently one soon after the separation of the Crocodile branch from the main stem. The modern Gavial type appears to have been developed about the same time, as the form was well established in the Upper Cretaceous genus, *Thoracosaurus*. The Teleosaurian group, with biconcave vertebræ, evidently the parent stock of Crocodilians, became extinct with *Hyposaurus* of the same horizon leaving the Crocodile and Gavial, with their more perfect procœlian vertebræ, to contend for the supremacy. In the early Eocene, both of these types were abundant, but some of the Crocodiles possessed characters pointing towards the Alligators, which do not appear to have been completely differentiated until later.

Nothing is really known to-day of the earlier genealogy of the *Pterosauria*, but our American forms, without teeth, are clearly the last stage in their development before this peculiar group became extinct. The oldest European form, *Dimorphodon*, from the Lower Lias, had the entire jaws armed with teeth, and was provided with a long tail. The later genus *Pterodactylus* retained the teeth, but had essentially lost the tail; while *Ramphorhynchus* had retained the elongated tail, but had lost the teeth from the fore part of both jaws. In the genus *Pteranodon* from the American

[6] See note on page 220, also section.

Cretaceous, the teeth are entirely absent, and the tail is a mere rudiment. In the gradual loss of the teeth and tail, these reptiles followed the same path as Birds, and might thus seem to approach them, as many have supposed. This resemblance, however, is only a superficial one, as a study of the more important characters of the Pterodactyles shows that they are an aberrant type of Reptiles, totally off the line through which the Birds were developed. The announcement made not long since in Europe, and accepted by some American authors, that the *Pterosauria*, in consequence of certain points in their structure, were essentially Birds, is directly disproved by American specimens, far more perfect than those on which the conclusion was based.

It is now generally admitted by biologists who have made a study of the vertebrates, that Birds have come down to us through the Dinosaurs, and the close affinity of the latter with recent Struthious Birds will hardly be questioned. The case amounts almost to a demonstration, if we compare, with Dinosaurs, their contemporaries, the Mesozoic Birds. The classes of Birds and Reptiles, as now living, are separated by a gulf so profound that a few years since it was cited by the opponents of evolution as the most important break in the animal species, and one which that doctrine could not bridge over. Since then, as Huxley has clearly shown, this gap has been virtually filled by the discovery of bird-like Reptiles and reptilian Birds. *Compsognathus* and *Archæopteryx* of the old World, and *Ichthyornis* and *Hesperornis* of the New, are the stepping stones by which the evolutionist of to-day leads the doubting brother across the shallow remnant of the gulf, once thought impassable.

It remains now to consider the highest group of the Animal Kingdom, the class *Mammalia*, which includes Man. Of the existence of this class before the Trias, we have no evidence, either in this country or in the Old World, and it is a significant fact that at essentially the same horizon in each hemisphere, similar low forms of Mammals make their appearance. Although only a few incomplete specimens have been discovered, they are characteristic and well preserved, and all are apparently Marsupials, the lowest Mammalian group which we know in this country, living or fossil. The American Triassic Mammals are known at present only from two smaller lower jaws, on which is based the genus *Dromatherium*,

supposed to be related to the insect-eating *Myrmecobius*, now living in Australia.

Although the Jura of Europe has yielded other similar Mammals, we have as yet none of this class from that formation ;[7] while, from rocks of Cretaceous age, no Mammals are known in any part of the world. This is especially to be regretted, as it is evidently to the Cretaceous that we must look for the first representatives of many of our present groups of Mammals, as well as for indications of their more ancient lineage. That some discovery of this nature from the Cretaceous is near at hand, I cannot doubt, when I consider what the last few years have brought to light in the Eocene.

In the lowest Tertiary beds of this country, a rich Mammalian fauna suddenly makes its appearance, and from that time through the Age of Mammals to the present, America has been constantly occupied by this type of life in the greatest diversity of form. Fortunately, a nearly continuous record of this life, as preserved, is now accessible to us, and ensures great additions to our knowledge of the genealogy of Mammals, and perhaps the solution of more profound problems. Before proceeding to discuss in detail American fossil *Mammalia*, it is important to define the divisions of time indicated in our Tertiary and Post-Tertiary deposits, as these in many cases mark successive stages in the development of the mammals.

The boundary line between the Cretaceous and Tertiary in the region of the Rocky Mountains has been much in dispute during the last few years, mainly in consequence of the uncertain geological bearings of the fossil plants found near this horizon. The accompanying invertebrate fossils have thrown little light on the question, which is essentially, whether the great Lignite series of the West is uppermost Cretaceous, or lowest Eocene. The evidence of the numerous vertebrate remains is, in my judgment, decisive, and in favor of the former view.

This brings up an important point in Palæontology, one to which my attention was drawn several years since, namely: the comparative value of different groups of fossils in marking geological time. In examining the subject with some care, I found that, for this purpose, plants, as their nature indicates, are most unsatisfactory witnesses; that invertebrate animals are much

[7] A small marsupial from the upper Jurassic of Wyoming has recently been described by the writer, and named *Dryolestes priscus*.—O. C. M.

better; and that vertebrates afford the most reliable evidence of climatic and other geological changes. The subdivisions of the latter group, moreover, and in fact all forms of animal life, are of value in this respect, mainly according to the perfection of their organization, or zoological rank. Fishes, for example, are but slightly affected by changes that would destroy Reptiles or Birds, and the higher Mammals succumb under influences that the lower forms pass through in safety. The more special applications of this general law, and its value in geology, will readily suggest themselves.

The evidence offered by fossil remains is, in the light of this law, conclusive, that the line, if line there be, separating our Cretaceous from the Tertiary, must at present be drawn where the Dinosaurs and other Mesozoic vertebrates disappear, and are replaced by the Mammals, henceforth the dominant type.[8]

The Tertiary of Western America comprises the most extensive series of deposits of this age known to geologists, and important breaks in both the rocks and the fossils separate it into three well-marked divisions. These natural divisions are not the exact equivalents of the Eocene, Miocene, and Pliocene of Europe, although usually so considered, and known by the same names; but, in general, the fauna of each appears to be older than that of its corresponding representative in the other hemisphere; an important fact, not hitherto recognized. This partial resemblance of our extinct faunas to others in regions widely separated, where the formations are doubtless somewhat different in geological age, is precisely what we might expect, if, as was probable, the main migrations took place from this Continent. It is better at once to recognize this principle, rather than attempt to bring into exact parallelism formations that were not strictly contemporaneous.

The freshwater Eocene deposits of our Western Territories, which are in the same region at least two miles in vertical thickness, may be separated into three distinct subdivisions. The lowest of these, resting unconformably on the Cretaceous, has been termed the Vermilion Creek, or Wahsatch Group. It contains a well-marked mammalian fauna, the largest and most characteristic genus of which is the ungulate *Coryphodon*, and hence I have called these deposits the Coryphodon Beds. The middle Eocene

[8] See frontispiece, section.

strata, which have been termed the Green River and Bridger Series, may be designated as the Dinoceras Beds, as the gigantic animals of this order are only found here. The uppermost Eocene, or the Uintah Group, is especially well characterized by large mammals of the genus *Diplacodon*, and hence may be termed the Diplacodon Beds. The fauna of each of these three subdivisions was essentially distinct, and the fossil remains of each were entombed in different and successive ancient lakes. It is important to remember that these Eocene lake-basins all lie between the Rocky Mountains on the east and the Wahsatch Range on the west, or along the high central plateau of the Continent. As these mountain chains were elevated, the enclosed Cretaceous sea cut off from the ocean, gradually freshened, and formed these extensive lakes, while the surrounding land was covered with a luxuriant tropical vegetation, and with many strange forms of animal life. As the upward movement of this region continued, these lake-basins, which for ages had been filling up, preserving in their sediments a faithful record of Eocene life-history, were slowly drained by the constant deepening of the outflowing rivers, and they have since remained essentially dry land.

The Miocene lake-basins are on the flanks of this region, where only land had been since the close of the Cretaceous. These basins contain three faunas, nearly or quite distinct. The lowest Miocene, which is only found east of the Rocky Mountains, alone contains the peculiar mammals known as the *Brontotheridæ*, and these deposits may be called the Brontotherium Beds. The strata next above, which represent the middle Miocene, have as their most characteristic fossil the genus *Oreodon*, and are known as the Oreodon Beds. The upper Miocene, which occurs in Oregon, is of great thickness, and from one of its most important fossils, *Miohippus*, may be designated as the Miohippus Series. The climate here during this period was warm temperate.

Above the Miocene, east of the Rocky Mountains and on the Pacific Coast, the Pliocene is well developed, and is rich in vertebrate remains. The strata rest unconformably on the Miocene, and there is a well-marked faunal change at this point, modern types now first making their appearance. For these reasons, we are justified in separating the Miocene from the Pliocene at this break; although in Europe where no marked break exists, the line seems to have been drawn at a somewhat higher horizon. Our

Pliocene forms essentially a continuous series, although the upper beds may be distinguished from the lower by the presence of a true *Equus*, and some other existing genera. The Pliocene climate was similar to that of the Miocene. The Post-pliocene beds contain many extinct mammals, and may thus be separated from recent deposits.

Returning now to our subject from this geological digression, —which will hardly be deemed unprofitable, since I have given you in few words the results of a great deal of my own hard mountain work,— let us consider the Tertiary mammals, as we know them from the remains already discovered, and attempt to trace the history of each order down to the present time. We have seen that a single small Marsupial, from the Trias, is the only mammal found in all the American rocks below the Eocene; and yet in beds of this age, immediately over the Chalk, fossil mammals of many different kinds abound.

The Marsupials, strange to say, are here few in number, and diminutive in size; and have as yet been identified only by fragmentary specimens, and most of them too imperfect for accurate description. In the higher Eocene deposits, this group is more abundant, but still represented by small animals, most of them insectivorous, or carnivorous in habit, like the existing Opossum. From the Miocene and Pliocene, no remains of Marsupials have been described. From the Post-tertiary, only specimens nearly allied to those now living are known, and most of these were found in the caves of South America.

The Edentate Mammals are evidently an American type, and on this Continent attained a great development in numbers and size. No Eocene Edentates have been found here, and although their discovery in this formation has been announced, the identification proves to have been erroneous. In the Miocene of the Pacific Coast, a few fossils have been discovered which belong to animals of this group, and to the genus *Moropus*. There are two species, one about as large as a Tapir, and the other nearly twice that size. This genus is the type of a distinct family, the *Moropodidæ*. In the lower Pliocene above, well preserved remains of Edentates of very large size have been found at several widely separated localities in Idaho and California. These belong to the genus *Morotherium*, of which two species are known. East of the Rocky Mountains, in the lower Pliocene of Nebraska, a large

species, apparently of the genus *Moropus*, has been discovered. The horizon of these later fossils corresponds nearly with beds in Europe that have been called Miocene. In the Post-pliocene of North America, gigantic Edentates were very numerous and widely distributed, but all disappeared with the close of that period. These forms were essentially huge Sloths, and the more important genera were *Megatherium*, *Mylodon* and *Megalonyx*. The genera *Megalocnus* and *Myomorphus* have been found only in Cuba.

In South America during the Pliocene or Post-pliocene, enormous Edentates were still more abundant, and their remains are usually in such perfect preservation as to suggest a very recent period for their extinction. The Sloth tribe is represented by the huge *Mylodon*, *Megatherium*, *Megalonyx*, *Cœlodon*, *Ochotherium*, *Gnathopis*, *Lestodon*. *Scelidotherium*, *Sphœnodon;* and among the Armadillos were *Chlamydotherium*, *Eurydon*, *Glyptodon*, *Heterodon*, *Pachytherium*, and *Schistopleurum*. *Glossotherium*, another extinct genus, is supposed to be allied to the Ant-eaters.

It is frequently asserted, and very generally believed, that the large number of huge *Edentata*, which lived in North America during the Post-pliocene, were the results of an extensive migration from South America soon after the elevation of the Isthmus of Panama, near the close of the Tertiary. No conclusive proof of such migration has been offered, and the evidence, it seems to me, so far as we now have it, is directly opposed to this view. No undoubted Tertiary Edentates have yet been discovered in South America, while we have at least two species in our Miocene, and during the deposition of our lower Pliocene, large individuals of this group were not uncommon as far north as the forty-third parallel of latitude, on both sides of the Rocky Mountains. In view of these facts, and others which I shall lay before you, it seems more natural to conclude from our present knowledge, that the migration, which no doubt took place, was from north to south. The Edentates finding thus in South America a congenial home flourished greatly for a time, and although the larger forms are now all extinct, diminutive representatives of the group still inhabit the same region.

The *Cetacea* first appear in the Eocene, as in Europe, and are comparatively abundant in deposits of this age on the Atlantic Coast. The most interesting remains of this order, yet found, belong to the *Zeuglodontidæ*, which are carnivorous whales, and

the only animals of the order with teeth implanted by two roots. The principal genera of this family are *Zeuglodon* and *Squalodon*, the former genus being represented by gigantic forms, some of which were seventy feet in length. The genus *Saurocetes*, which includes some small animals of this group, has been found in South America. The Dolphin family (*Delphinidæ*) are well represented in the Miocene, both on the Atlantic and Pacific Coast. The best known genus is *Priscodelphinus*, of which several species have been described. Several other generic names which have been applied to fragments need not here be enumerated. In none of the Tertiary species of this family were the cervical vertebræ ankylosed. The Sperm Whales (*Catodontidæ*) were also abundant throughout the Tertiary, and with them in the earlier beds, various Ziphioid forms have been found. The toothless *Balænidæ* are only known with certainty as fossils from the later Tertiary and more recent deposits.

The Sirenians, which appear first in the Eocene of the Old World, occur in the Miocene of our Eastern Coast, and throughout the later Tertiary. The specimens described have all been referred to the genus *Manatus*, and seem closely related to our living species. In the Tertiary of Jamaica, a skull has been found which indicates a new genus, *Prorastomus*, also allied to the existing Manatee. The genus *Rhytina*, once abundant on our Northwest Coast, has recently become extinct.

The Ungulates are the most abundant Mammals in the Tertiary, and the most important; since they include a great variety of types, some of which we can trace through their various changes down to the modified forms that represent them to-day. Of the various divisions in this comprehensive group, the Perissodactyle, or odd-toed Ungulates, are evidently the oldest, and throughout the Eocene are the prevailing forms. Although all of the Perissodactyles of the earlier Tertiary are more or less generalized, they are still quite distinct from the Artiodactyles, even at the base of the Eocene. One family, however, the *Coryphodontidæ*, which is well represented at this horizon, both in America and Europe, although essentially Perissodactyle, possesses some characters which point to a primitive Ungulate type from which the present orders have been evolved. Among these characters are the diminutive brain, which in size and form approaches that of the Reptiles, and also the five-toed feet, from which all the various forms of the

mammalian foot have been derived. Of this family, only a single genus *Coryphodon* (*Bathmodon*), is known, but there were several distinct species. They were the largest mammals of the lower Eocene, some exceeding in size the existing Tapirs.

In the middle Eocene, West of the Rocky Mountains, a remarkable group of ungulates makes its appearance. These animals nearly equalled the Elephant in size, but had shorter limbs. The skull was armed with two or three pairs of horn-cores, and with enormous canine tusks. The brain was proportionally smaller than in any other land mammal. The feet had five toes, and resembled in their general structure those of *Coryphodon*, thus indicating some affinity with that genus. These mammals resemble in some respects the Perissodactyles, and in others the Proboscidians, yet differ so widely from any known Ungulates, recent or fossil, that they must be regarded as forming a distinct order, the *Dinocerata*. Only three genera are known, *Dinoceras*, *Tinoceras*, and *Uintatherium*, but quite a number of species have been described. During the later part of the middle Eocene, these animals were very abundant for a short time, and then became extinct, leaving apparently no successors, unless possibly we have in the Proboscidians their much modified descendants. Their genetic connection with the Coryphodonts is much more probable, in view of what we now know of the two groups.

Besides these peculiar Mammals, which are extinct, and mainly of interest to the Biologist, there were others in the early Tertiary which remind us of those at present living around us. When a student in Germany some twelve years ago, I heard a world-renowned Professor of Zoology gravely inform his pupils that the Horse was a gift of the Old World to the New, and was entirely unknown in America until introduced by the Spaniards. After the lecture, I asked him whether no earlier remains of horses had been found on this Continent, and was told in reply that the reports to that effect were too unsatisfactory to be presented as facts in science. This remark led me, on my return, to examine the subject myself, and I have since unearthed, with my own hands, not less than thirty distinct species, of the horse tribe in the Tertiary deposits of the West alone; and it is now, I think, generally admitted that America is, after all, the true home of the horse.

I can offer you no better illustration than this of the advance vertebrate palæontology has made during the last decade, or of

the important contributions to this progress which our Rocky Mountain region has supplied.

The oldest representative of the horse, at present known, is the diminutive *Eohippus* from the lower Eocene. Several species have been found, all about the size of a fox. Like most of the early mammals, these Ungulates had forty-four teeth, the molars with short crowns, and quite distinct in form from the premolars. The ulna and the fibula were entire and distinct, and there were four well developed toes and a rudiment of another on the fore feet, and three toes behind. In the structure of the feet, and in the teeth, the *Eohippus* indicates unmistakably that the direct ancestral line to the modern horse has already separated from the other Perissodactyles. In the next higher division of the Eocene, another genus (*Orohippus*) makes its appearance, replacing *Eohippus*, and showing a greater, although still distant, resemblance to the Equine type. The rudimentary first digit of the fore foot has disappeared, and the last premolar has gone over to the molar series. *Orohippus* was but little larger than *Eohippus*, and in most other respects very similar. Several species have been found in the same horizon with *Dinoceras*, and others lived during the upper Eocene with *Diplacodon*, but none later.[9]

Near the base of the Miocene, in the Brontotherium beds, we find a third closely allied genus, *Mesohippus*, which is about as large as a sheep, and one stage nearer the horse. There are only three toes and a rudimentary splint bone on the fore feet, and three toes behind. Two of the premolar teeth are quite like the molars. The ulna is no longer distinct, or the fibula entire, and other characters show clearly that the transition is advancing. In the upper Miocene, *Mesohippus* is not found, but in its place a fourth form, *Miohippus*, continues the line. This genus is near the *Anchitherium* of Europe, but presents several important differences. The three toes in each foot are more nearly of a size, and a rudiment of the fifth metacarpal bone is retained. All the known species of this genus are larger than those of *Mesohippus*, and none pass above the Miocene.

The genus *Protohippus*, of the lower Pliocene, is yet more equine, and some of its species equalled the ass in size. There are still

[9] Since this address was delivered, I have found in the Diplacodon beds a new genus of Equines (*Epihippus*), which was larger than *Orohippus*, and had the same number of toes, but had two premolar teeth like the molars. — O. C. M.

three toes on each foot, but only the middle one, corresponding to the single toe of the horse, comes to the ground. This genus resembles most nearly the *Hipparion* of Europe. In the Pliocene, we have the last stage of the series before reaching the horse, in the genus *Pliohippus*, which has lost the small hoofiets, and in other respects is very equine. Only in the upper Pliocene, does the true *Equus* appear, and complete the genealogy of the Horse, which in the Post-tertiary roamed over the whole of North and South America, and soon after became extinct. This occurred long before the discovery of the Continent by Europeans, and no satisfactory reason for the extinction has yet been given. Besides the characters I have mentioned, there are many others, in the skeleton, skull, teeth, and brain of the forty or more intermediate species, which show that the transition from the Eocene *Eohippus* to the modern *Equus* has taken place in the order indicated, and I believe the specimens now at New Haven will demonstrate the fact to any anatomist. They certainly carried prompt conviction to the first of anatomists, who was the honored guest of the Association a year ago, whose genius had already indicated the later genealogy of the horse in Europe, and whose own researches so well qualified him to appreciate the evidence here laid before him. Did time permit, I might give you at least a probable explanation of this marvellous transition, but justice to the comrades of the horse in his long struggle for existence demands that some notice of their efforts should be placed on record.

Besides the Horse and his congeners, the only existing Perissodactyles are the Rhinoceros and the Tapir. The last is the oldest type, but the Rhinoceros had near allies throughout the Tertiary; and, in view of the continuity of the equine line, it is well worth while to attempt to trace his pedigree. At the bottom of the Eocene, in our Western lake-basins, the tapiroid genus *Helaletes* is found, represented by numerous small mammals hardly larger than the diminutive horses of that day. In the following epoch of the Eocene, the closely allied *Hyrachyus* was one of the most abundant animals. This genus was nearly related to the *Lophiodon* of Europe, and in its teeth and skeleton strongly resembled the living Tapir, whose ancestry, to this point, seems to coincide with that of the Rhinoceros we are considering. Strangely enough, the Rhinoceros line, before it becomes distinct, separates into two branches. In the upper part of the Dinoceras Beds we have

the genus *Colonoceras*, which is really a *Hyrachyus* with a transverse pair of very rudimentary horn-cores on the nasal-bones. In the lower Miocene west of the Rocky Mountains, this line seems to pass on through the genus *Diceratherium*, and in the higher Miocene this genus is well represented. Some of the species nearly equalled in size the existing Rhinoceros, which *Diceratherium* strongly resembled. The main difference between them is a most interesting one. The rudimentary horn-cores on the nasals, seen in *Colonoceras*, are in *Diceratherium* developed into strong bony supports for horns, which were placed transversely, as in the Ruminants, and not on the median line, as in all existing forms of Rhinoceros. In the Pliocene of the Pacific Coast, a large Rhinoceros has been discovered, which may be a descendant of *Diceratherium*, but as the nasal bones have not been found, we must wait for further evidence on this point. Returning now to the other branch of the Rhinoceros group, which left their remains mainly East of the Rocky Mountains, we find that all the known forms are hornless. The upper Eocene genus *Amynodon* is the oldest known Rhinoceros, and by far the most generalized of the family. The premolars are all unlike the molars, the four canines are of large size, but the inner incisor in each jaw is lost in the fully adult animal. The nasals were without horns. There were four toes in front, and three behind. The genus *Hyracodon*, of the Miocene, which is essentially a Rhinoceros, has a full set of incisor and canine teeth; and the molars are so nearly like those of its predecessor *Hyrachyus*, that no one will question the transformation of the older into the newer type. *Hyracodon*, however, appears to be off the true line, for it has but three toes in front. In the higher Miocene beds, and possibly with *Hyracodon*, occurs a larger Rhinoceros, which has been referred to the genus *Aceratherium*. This form has lost the canine and one incisor above, and two incisors below. In the Pliocene are several species closely related, and of large size. Above the Pliocene in America, no vestiges of the Rhinoceros have been found, and our American forms doubtless became extinct at the close of this period.

The Tapir is clearly an old American type, and we have seen that, in the Eocene, the genera *Helaletes* and *Hyrachyus* were so strongly tapiroid in their principal characters, that the main line of descent probably passed through them. It is remarkable that the Miocene of the West, so greatly developed as it is on both

sides of the Rocky Mountains, should have yielded but a few fragments of tapiroid mammals, and the same is true of the Pliocene of that region. In the Miocene of the Atlantic Coast, too, only a few imperfect specimens have been found. These forms all apparently belong to the genus *Tapiravus*, although most of them have been referred to *Lophiodon*, a lower Eocene type. In the Post-tertiary, a true *Tapirus* was abundant, and its remains have been found in various parts of North America. The line of descent, although indistinct through the middle and upper Tertiary, was doubtless continuous in America, and several species exist at present, from Mexico southward. It is worthy of notice that the species North of the Isthmus of Panama appear all to be generically distinct from those of South America.

In addition to these three Perissodactyle types, which, as the fittest, have alone survived, and whose lineage I have endeavored to trace, there were many others in early Tertiary times. Some of these disappeared with the close of the Eocene, while others continued, and assumed strange specialized shapes in the Miocene, before their decline and extinction. One series of the latter deserves especial mention, as it includes one of the most interesting families of our extinct animals. Among the large mammals in the lower Eocene is *Limnohyus*, a true Perissodactyle, but only known here from fragments of the skeleton. In the next higher beds, this genus is well represented, and with it is found a nearly allied form, *Palæosyops*. In the upper Eocene, both have left the field, and the genus *Diplacodon*, a very near relative, holds the supremacy. The line seems clear through these three genera, but on crossing the break into the Miocene, we have, apparently as next of kin, the huge *Brontotheridæ*. These strange beasts show in their dentition and some other characters the same transition steps beyond *Diplacodon*, which that genus had made beyond *Palæosyops*. The *Brontotheridæ* were nearly as large as the Elephant, but had much shorter limbs. The skull was elongated, and had a transverse pair of large horn-cores on the maxillaries, in front of the orbits, like the middle pair in *Dinoceras*. There were four toes in front, and three behind, and the feet were similar to those of the Rhinoceros. There are four genera in this group, *Brontotherium; Diconodon; Menodus* (*Titanotherium*); and *Megacerops*, which have been found only in the lowest Miocene, east of the Rocky Mountains.

In the higher Miocene beds of Oregon, an allied genus, *Chalicotherium*, makes its appearance. It is one stage further on in the transition, and perhaps a descendant of the *Brontotheridæ;* but here, so far as is known, the line disappears. It is a suggestive fact, that this genus has now been found in Western America, China, India, Greece, Germany and France, indicating thus, as I believe, the path by which many of our ancient mammals helped to people the so-called Old World.

The Artiodactyles, or even-toed Ungulates, are the most abundant of the larger mammals now living; and the group dates back at least to the lowest Eocene. Of the two well marked divisions of this order, the Bunodonts and the Selenodonts, as happily defined by Kowalevsky, the former is the older type, which must have separated from the Perissodactyle line after the latter had become differentiated from the primitive Ungulate. In the Coryphodon Beds of New Mexico, occurs the oldest Artiodactyle yet found, but it is at present known only from fragmentary specimens. These remains are clearly Suilline in character, and belong to the genus *Eohyus*. In the beds above, and possibly even in the same horizon, the genus *Helohyus* is not uncommon, and several species are known. The molar teeth of this genus are very similar to those of the Eocene *Hyracotherium*, of Europe, which is supposed to be a Perissodactyle, while *Helohyus* certainly is not, but apparently a true lineal ancestor of the existing pigs. In every vigorous primitive type which was destined to survive many geological changes, there seems to have been a tendency to throw off lateral branches, which became highly specialized, and soon died out, because they were unable to adapt themselves to new conditions. The narrow path of the persistent Suilline type, throughout the whole Tertiary, is strewn with the remains of such ambitious offshoots, while the typical pig, with an obstinacy never lost, has held on in spite of Catastrophes and Evolution, and still lives in America to-day. In the lower Eocene, we have in the genus *Parahyus* apparently one of these short-lived, specialized branches. It attained a much larger size than the true lineal forms, and the number of its teeth was reduced. In the Dinoceras Beds, or middle Eocene, we have still, on or near the true line, *Helohyus*, which is the last of the series known from the American Eocene. All these early Suillines, with the possible exception of *Parahyus*, appear to have had at least four toes, all of usable size.

In the lower Miocene we find the genus *Perchœrus*, seemingly a true Suilline, and with it remains of a larger form, *Elotherium*, are abundant. The latter genus occurs in Europe in nearly the same horizon, and the specimens known from each Continent agree closely in general characters. The name *Pelonax* has been applied erroneously to some of the American forms; but the specimens on which it was based clearly belong to *Elotherium*. This genus affords another example of the aberrant Suilline offshoots, already mentioned. Some of the species were nearly as large as a Rhinoceros, and in all there were but two serviceable toes; the outer digits, seen in living animals of this group, being represented only by small rudiments concealed beneath the skin. In the upper Miocene of Oregon, Suillines are abundant, and almost all belong to the genus *Thinohyus*, a near ally of the modern Peccary (*Dicotyles*), but having a greater number of teeth, and a few other distinguishable features. In the Pliocene, Suillines are still numerous, and all the American forms yet discovered are closely related to *Dicotyles*. The genus *Platygonus* is represented by several species, one of which was very abundant in the Post-tertiary of North America, and is apparently the last example of a side branch, before the American Suillines culminate in existing Peccaries. The feet in this species are more specialized than in the living forms, and approach some of the peculiar features of the ruminants; as for example a strong tendency to coalesce in the metapodial bones. The genus *Platygonus* became extinct in the Post-Tertiary, and the later and existing species are all true Peccaries.

No authenticated remains of the genera *Sus*, *Porcus*, *Phacochœrus*, or the allied *Hippopotamus*, the Old World Suillines, have been found in America, although several announcements to that effect have been made.

In the series of generic forms between the lower Eocene *Eohyus* and the existing *Dicotyles*, which I have very briefly discussed, we have apparently the ancestral line ending in the typical American Suillines. Although the demonstration is not yet as complete as in the lineage of the Horse, this is not owing to want of material, but rather to the fact that the actual changes which transformed the early Tertiary pig into the modern Peccary were comparatively slight, so far as they are indicated in the skeletons preserved, while the lateral branches were so numerous as to confuse the

line. It is clear, however, that from the close of the Cretaceous to the Post-tertiary, the Bunodont Artiodactyles were especially abundant on this Continent, and only recently have approached extinction.

The Selenodont division of the Artiodactyles is a more interesting group, and, so far as we now know, makes its first appearance in the upper Eocene of the West, although forms, apparently transitional, between it and the Bunodonts occur in the Dinoceras Beds, or middle Eocene. These belong to the genus *Homacodon*, which is very nearly allied to *Helohyus*, and but a single step away from this genus toward the Selenodonts. By a fortunate discovery, a nearly complete skeleton of this rare intermediate form has been brought to light, and we are thus enabled to define its characters. Several species of *Homacodon* are known, all of small size. This primitive Selenodont had forty-four teeth, which formed a nearly continuous series.

The molar teeth are very similar to those of *Helohyus*, but the cones on the crowns have become partially triangular in outline, so that when worn, the Selenodont pattern is clearly recognizable. The first and second upper molars, moreover, have three distinct posterior cusps, and two in front; a peculiar feature, which is seen also in the European genera *Dichobune* and *Cainotherium*. There were four toes on each foot, and the metapodial bones were distinct. The type species of this genus was about as large as a cat. With *Helohyus*, this genus forms a well marked family, the *Helohyidæ*.

In the *Diplacodon* horizon of the upper Eocene, the Selenodont dentition is no longer doubtful, as it is seen in most of the *Artiodactyla*, yet found in these beds. These animals are all small, and belong at least to three distinct genera. One of these, *Eomeryx*, closely resembles *Homacodon*, in most of its skeleton, and has four toes, but its teeth show well marked crescents, and a partial transition to the teeth of *Hyopotamus*, from the Eocene of Europe. With this genus, is another (*Parameryx*), also closely allied to *Homacodon*, but apparently a straggler from the true line, as it has but three toes behind. The most pronounced Selenodont in the upper Eocene is the *Oromeryx*, which genus appears to be allied to the existing Deer family, or *Cervidæ*, and if so is the oldest known representative of the group. These facts are important, as it has been supposed, until very recently, that our Eocene contained no even-hoofed mammals.

In the lowest Miocene of the West, no true crescent-toothed *Artiodactyla* have as yet been identified, with the exception of a single species of *Hyopotamus;* but in the overlying beds of the middle Miocene, remains of the *Oreodontidæ* occur in such vast numbers as to indicate that these animals must have lived in large herds around the borders of the lake-basins in which their remains have been entombed. These basins are now the denuded deserts, so well termed *Mauvaises Terres* by the early French trappers. The least specialized, and apparently the oldest, genus of this group is *Agriochœrus*, which so nearly resembles the older *Hyopotamus*, and the still more ancient *Eomeryx*, that we can hardly doubt that they all belonged to the same ancestral line. The typical Oreodonts are the genera *Oreodon* and *Eporeodon*, which have been aptly termed by Leidy, ruminating hogs. They had forty-four teeth, and four well developed toes on each foot. The true Oreodons, which were most numerous east of the Rocky Mountains, were about as large as the existing Peccary, while *Eporeodon*, which was nearly twice this size, was very abundant in the Miocene of the Pacific Slope.

In the succeeding Pliocene formation, on each side of the Rocky Mountains, the genus *Merychyus* is one of the prevailing forms, and continues the line on from the Miocene, where the true Oreodons became extinct. Beyond this, we have the genus *Merychochœrus*, which is so nearly allied to the last, that they would be united by many naturalists. With the close of the Pliocene, this series of peculiar ruminants abruptly terminates, no member surviving until the Post-tertiary, so far as known.

A most interesting line, that leading to the Camels and Llamas, separates from the primitive Selenodont branch in the Eocene, probably through the genus *Parameryx*. In the Miocene, we find in *Pœbrotherium* and some nearly allied forms unmistakable indications that the Cameloid type of ruminant had already become partially specialized, although there is a complete series of incisor teeth, and the metapodial bones are distinct. In the Pliocene, the Camel tribe was, next to the Horses, the most abundant of the larger mammals. The line is continued through the genus *Procamelus*, and perhaps others, and in this formation the incisors first begin to diminish, and the metapodials to unite. In the Post-tertiary we have a true *Auchenia* represented by several species, and others in South America, where the Alpacas and Llamas still

survive. From the Eocene almost to the present time, North America has been the home of vast numbers of the *Camelidæ*, and there can be little doubt that they originated here, and migrated to the Old World.

Returning once more to the Upper Eocene, we find another line of descent starting from *Oromeryx*, which, as we have seen, had apparently then just become differentiated from the older Bunodont type. Throughout the middle and upper Miocene, this line is carried forward by the genus *Leptomeryx* and its near allies, which resemble so strongly the Pliocene *Cervidæ* that they may fairly be regarded as their probable progenitors. Possibly some of these forms may be related to the *Tragulidæ*, but at present the evidence is against it.

The Deer family has representatives in the upper Miocene of Europe, which contains fossils strongly resembling the fauna of our lower Pliocene, a fact always to be borne in mind in comparing the horizon of any group in the two continents. Several species of *Cervidæ*, belonging to the genus *Cosoryx*, are known from the lower Pliocene of the West, and all have very small antlers, divided into a single pair of tynes. The statement recently published, that most of these antlers had been broken during the life of the animals, is unsupported by any evidence, and is erroneous. These Primitive Deer do not have the orbit closed behind, and they have all the four metapodial bones entire, although the second and fifth are very slender. In the upper Pliocene, a true *Cervus* of large size has been discovered. In the Post-tertiary, *Cervus*, *Alces* and *Tarandus* have been met with, the last far south of its present range. In the caves of South America, remains of *Cervus* have been found, and also two species of Antelopes, one referred to a new genus, *Leptotherium*.

The Hollow-horned Ruminants, in this country, appear to date back no further than to the lower Pliocene, and here only two species of *Bison* have as yet been discovered. In the Post-tertiary, this genus was represented by numerous individuals and several species, some of large size. The Musk Ox (*Ovibos*) was not uncommon during some parts of this epoch, and its remains are widely distributed.

No authentic fossil remains of true Sheep, Goats, or Giraffes have as yet been found on this continent.

The Proboscidians, which are now separated from the typical

Ungulates as a distinct order, make their first appearance in North America in the lower Pliocene, where several species of *Mastodon* have been found. This genus occurs, also, in the upper Pliocene, and in the Post-tertiary; although some of the remains attributed to the latter are undoubtedly older. The Pliocene species all have a band of enamel on the tusks, and some other peculiarities observed in the oldest Mastodons of Europe, which are from essentially the same horizon. Two species of this genus have been found in South America, in connection with the remains of extinct Llamas and Horses. The genus *Elephas* is a later form, and has not yet been identified in this country below the upper Pliocene, where one gigantic species was abundant. In the Post-pliocene, remains of this genus are numerous. The hairy Mammoth of the Old World (*Elephas primigenius*) was once abundant in Alaska, and great numbers of its bones are now preserved in the frozen cliffs of that region. This species does not appear to have extended east of the Rocky Mountain, or south of the Columbia River, but was replaced there by the American Elephant, which preferred a milder climate. Remains of the latter have been met with in Canada, throughout the United States, and in Mexico. The last of the American Mastodons and Elephants became extinct in the Post-tertiary.

The order *Toxodontia* includes two very peculiar genera, *Toxodon* and *Nesodon*, which have been found in the Post-tertiary deposits of South America. These animals were of huge size, and possessed such mixed characters that their affinities are a matter of considerable doubt. They are thought to be related to the Ungulates, Rodents, and Edentates, but, as the feet are unknown, this cannot at present be decided.

Macrauchenia and *Homalodontotherium* are two other peculiar genera from South America, now extinct, the exact affinities of which are uncertain. *Anoplotherium* and *Palæotherium*, so abundant in Europe, have not been found in our North American Tertiary deposits, although reported from South America.

Perhaps the most remarkable mammals yet found in America are the *Tillodontia*, which are comparatively abundant in the lower and middle Eocene. These animals seem to combine the characters of several different groups, viz.: the Carnivores, Ungulates, and Rodents. In the genus *Tillotherium*, the type of the order, and of the family *Tillotheridæ*, the skull resembles that of the

Bears; the molar teeth are of the ungulate type; while the large incisors are very similar to those of Rodents. The skeleton resembles that of the Carnivores, but the scaphoid and lunar bones are distinct, and there is a third trochanter on the femur. The feet are plantigrade, and each had five digits, all with long pointed claws. In the allied genus *Stylinodon*, which belongs to a distinct family, the *Stylinodontidæ*, all the teeth were rootless. Some of these animals were as large as a Tapir. The genus *Dryptodon* has been found only in the Coryphodon beds of New Mexico, while *Tillotherium* and *Stylinodon* occur in the middle Eocene of Wyoming. *Anchippodos* probably belongs to this group, which may perhaps include some other forms that have been named from fragmentary specimens.

The Rodents are an ancient type, and their remains are not unfrequently disinterred in the strata of our lowest fresh-water Eocene. The earliest known forms are apparently all related to the Squirrels, and the most common genus is *Sciuravus*, which continued throughout the Eocene. A nearly allied form, which may prove to be the same, is *Paramys*, the species of which are larger than those of the older type. In the Dinoceras beds, the genus *Colonomys* is found, and the specimens preserved point to the *Muridæ*, as the nearest living allies. A peculiar genus, *Apatemys*, which also occurs in the middle Eocene, has gliriform incisors, but the molars resemble those of Insectivores. All the Eocene Rodents are of small size, the largest being about as large as a rabbit.

In the middle and upper Miocene lake-basins of the West, Rodents abound, but all are of moderate size. The Hares first appear in the Oreodon beds, and continue in considerable numbers through the rest of the Tertiary and Post-tertiary to the present day. In these beds, the most common forms belong to the *Leporidæ*, and mainly to the genus *Palæolagus*. The Squirrel family is represented by *Ischyromys*, the *Muridæ* by the genus *Eumys*, and the Beavers by *Palæocastor*. In the upper Miocene of Oregon, most of the same genera are found, and with them some peculiar forms very unlike anything now living. One of these is the genus *Allomys*, possibly related to the flying squirrels, but having molar teeth somewhat like those of the Ungulates. In the Pliocene, east and west of the Rocky Mountains, Rodents continue abundant, but most of them belong to existing genera. Among these are *Castor*, *Hystrix*, *Cynomys*, *Geomys*, *Lepus* and *Hesperomys*. In

the Post-tertiary, the gigantic beaver, *Castoroides*, was abundant throughout most of North America. *Hydrochærus* has been found in South Carolina. In the caves of the island of Anguilla, in the West Indies, remains of large extinct Rodents belonging to the *Chinchillidæ* have been discovered.

The early Tertiary Rodents known from South America are the genera *Megamys*, *Theridromys*, and a large species referred to *Arvicola*. In Brazil, the Pliocene Rodents found are referred to the existing genera *Cavia*, *Kerodon*, *Lagostomus*, *Ctenomys*, *Hesperomys*, *Oxymycterus*, *Arvicola* and *Lepus*. A new genus, *Cardiodus*, described from this horizon, is a true Rodent, but the peculiar *Typotherium*, which has been referred to this order by some authorities, has perhaps other affinities. In the Post-tertiary the Rodents were very abundant in South America, as they are at present. The species are in most instances distinct from those now living, but the genera are nearly the same. The *Cariidæ* were especially numerous. *Cercolabes*, *Myopotamus*, and *Lagostomus* are also found, and two extinct genera, *Phyllomys*, and *Louchophorus*.

The *Cheiroptera*, or Bats, have not been found in this country below the middle Eocene, where two extinct genera, *Nyctilestes* and *Nyctitherium*, are each represented by numerous remains. These fossils all belong to small animals, and, so far as they have been investigated, show no characters of more than generic importance to distinguish them from the Bats of to-day. No other members of this group are known from our Tertiary. In the Post-tertiary, no extinct species of Bats have been found in North America, but from the caves of Brazil quite a number have been reported. These all belong to genera still living in South America, and most of them to the family *Phyllostomidæ*.

The Insectivores date back, in this country, at least to the middle Eocene. Here numerous remains occur which have been described as belonging to this order, although it is possible that some of them were insect-eating Marsupials. The best known genera are, *Hemiacodon*, *Centetodon*, *Talpavus*, and *Entomacodon;* all represented by animals of small size. In the Miocene, the bones of Insectivores are comparatively abundant, and the genera best determined are *Ictops* and *Leptictis*. A few specimens only have been found in the Pliocene and Post-pliocene, most of them related to the Moles. No extinct Insectivores are known from South America, and no member of the group exists there at present.

The *Carnivora*, or true flesh-eating animals, are an old type, well represented in the Eocene, and, as might be expected, these early forms are much less specialized than the living species. In the Coryphodon beds, the genus *Limnocyon*, allied to the *Pterodon* of the European Eocene, is abundant. Another genus, apparently distinct, is *Prototomus*, and several others have been named from fragmentary fossils. In the middle Eocene, Carnivores were still more numerous, and many genera have been discovered. One of these, *Limnofelis*, was nearly as large as a lion, and apparently allied to the cats, although the typical *Felidæ* seem not yet to have been differentiated. Another Carnivore of nearly equal size was *Orocyon*, which had short massive jaws and broad teeth. *Dromocyon* and *Mesonyx* were large animals, allied to *Hyænodon*. The teeth were narrow, and the jaws long and slender. Among the smaller Carnivores were *Vulpavus*, *Viverravus*, *Sinopa*, *Thinocyon*, and *Ziphacodon*.

In our Western Miocene, Carnivores are abundant, and make an approach to modern types. The *Felidæ* are well represented, the most interesting genus being *Machairodus*, which is not uncommon in the Oreodon beds on both sides of the Rocky Mountains. An allied genus is *Dinictis*, and several smaller Cats are known from about the same horizon. The *Canidæ* are represented by *Amphicyon*, a European genus, and by several species of *Canis*, or a very nearly allied form. The peculiar genus *Hyænodon*, found also in Europe, and the type of a distinct family, is abundant in the Miocene east of the Rocky Mountains, but has not yet been found on the Pacific Coast. In the Pliocene of both regions, the *Canidæ* are numerous, and all apparently belong to the existing genus *Canis*. The genus *Machairodus* is still the dominant form of the Cats, which are abundant, and for the most part belong to the genus *Felis*. The extinct *Leptarctus* is supposed to belong to the *Ursidæ*, and, if so, is the oldest American representative of this family. In the Post-pliocene, the extinct *Felidæ* include species nearly as large as a lion, and smaller forms very similar to those still living. Bears, Raccoons and Weasels have also been found.

In the Pliocene of South America, *Machairodus* represents the *Felidæ*, while the genera *Arctotherium* and *Hyænarctus* belong to the Bear family. Species of *Mustela* and *Canis* have also been found. In the caves of Brazil, the fauna of which is regarded as Post-pliocene, one species of *Machairodus* is known, and one of

Synalurus. *Canis* and *Icticyon*, still living in Brazil, and the extinct genus *Speothos*, represent the *Canidæ*. *Mephitis* and *Galictis*, among the Weasels, were also present, and with them species of *Nasua* and *Arctotherium*.

We come now to the highest group of Mammals, the Primates, which includes the Lemurs, the Apes, and Man. This order has a great antiquity, and even at the base of the Eocene we find it represented by several genera belonging to the lower forms of the group. In considering these interesting fossils, it is important to have in mind that the Lemurs, which are usually regarded as Primates, although at the bottom of the scale, are only found at the present day in Madagascar and the adjacent regions of the globe. All the American Monkeys, moreover, belong to one group, much above the Lemurs, while the Old World Apes are higher still, and most nearly approach Man.

In the lower Eocene of New Mexico, we find a few representatives of the earliest known Primates, and among them are the genera *Lemuravus* and *Limnotherium;* each the type of a distinct family. These genera became very abundant in the middle Eocene of the West, and with them are found many others, all however, included in the two families, *Lemuravidæ* and *Limnotheridæ*. *Lemuravus* appears to have been most nearly allied to the Lemurs, and is the most generalized form of the Primates yet discovered. It had forty-four teeth, forming a continuous series, above and below. The brain was nearly smooth, and of moderate size. The skeleton most resembles that of the Lemurs. A nearly allied genus, belonging to the same family, is *Hyopsodus*. *Limnotherium* (*Tomitherium*) also is nearly related to the Lemurs, but shows some affinities with the South American Marmosets. This genus had forty teeth. The brain was nearly smooth, and the cerebellum large, and placed mainly behind the cerebrum. The orbits are open behind, and the lachrymal foramen is outside the orbit. Other genera belonging to the *Limnotheridæ* are *Nothurctos*, *Hipposyus*, *Microsyops*, *Palæacodon*, *Thinolestes*, and *Telmatolestes*. Besides these, *Antiacodon* (*Anaptomorphus*), *Bathrodon*, and *Mesacodon* should probably be placed in the same group. In the Diplacodon Beds, or Upper Eocene, no remains of Primates have yet been detected, although they will doubtless be found there.[10]

[10] A small species of *Hyopsodus* (*H. gracilis*), from this horizon has recently been determined by the writer.— O. C. M.

All the Eocene Primates known from American strata are low generalized forms, with characters in the teeth, skeleton, and feet that suggest relationships with the Carnivores, and even with the Ungulates. These resemblances have led palæontologists to refer some imperfect specimens to both these orders.

In the Miocene lake basins of the West, only a single species of the Primates has been identified with certainty. This was found in the Oreodon Beds of Nebraska, and belongs to the genus *Laopithecus*, apparently related both to the *Limnotheridæ* and to some existing South American Monkeys. In the Pliocene and Post-pliocene of North America, no remains of Primates have yet been found.

In the Post-pliocene deposits of the Brazilian caves, remains of Monkeys are numerous, and mainly belong to extinct species of *Callithrix*, *Cebus*, and *Jacchus*, all living South American genera. Only one extinct genus, *Protopithecus*, which embraced animals of large size, has been found in this peculiar fauna.

It is a noteworthy fact, that no traces of any Anthropoid Apes, or indeed of any Old World Monkeys, have yet been detected in America. Man, however, the highest of the Primates, has left his bones and his works from the Arctic Circle to Patagonia. Most of these specimens are clearly Post-tertiary, although there is considerable evidence pointing to the existence of Man in our Pliocene. All the remains yet discovered belong to the well-marked genus *Homo*, and apparently to a single species, at present represented by the American Indian.

In this rapid review of Mammalian life in America, from its first known appearance in the Trias down to the present time, I have endeavored to state briefly the introduction and succession of the principal forms in each natural group. If time permitted, I might attempt the more difficult task of trying to indicate what relations these various groups may possibly bear to each other; what connection the ancient Mammals of this continent have with the corresponding forms of the Old World; and, most important of all, what real progress Mammalian life has here made since the beginning of the Eocene. As it is, I can only say, in summing up, that the Marsupials are clearly the remnants of a very ancient fauna, which occupied this continent millions of years ago, and from which the other Mammals were doubtless all derived, although the direct evidence of the transformation is wanting.

Although the Marsupials are nearly related to the still lower Monotremes, now living in the Australian Region, we have as yet no hint of the path by which these two groups became separated from the inferior vertebrates. Neither have we to-day much light as to the genetic connection existing between Marsupials and the placental Mammalia, although it is possible that the different orders of the latter had their origin each from a separate group of the Marsupials.

The presence, however, of undoubted Marsupials in our lower and middle Eocene, some of them related to the genus *Didelphys*, although remotely, is important evidence as to the introduction of these animals into America. Against this, their supposed absence in our Miocene and Pliocene can have but limited weight, when taken in connection with the fact that they flourished in the Post-tertiary, and are still abundant. The evidence we now have is quite as strongly in favor of a migration of Marsupials from America to the Old World, as the reverse, which has been supposed by some naturalists. Possibly, as Huxley has suggested, both countries were peopled with these low mammals from a continent now submerged.

The Edentate mammals have long been a puzzle to Zoologists, and up to the present time no clew to their affinities with other groups seems to have been detected. A comparison of the peculiar Eocene Mammals which I have called the *Tillodontia*, with the least specialized Edentates, brings to light many curious resemblances in the skull, teeth, skeleton and feet. These suggest relationship, at least, and possibly we may yet find here the key to the Edentate genealogy. At present, the Tillodonts are all from the lower and middle Eocene, while *Moropus*, the oldest edentate genus, is found in the middle Miocene, and one species in the lower Pliocene.

The Edentates have been usually regarded as an American type, but the few living forms in Africa, and the Tertiary species in Europe, the oldest known, have made the land of their nativity uncertain. I have already given you some reasons for believing that the Edentates had their first home in North America, and migrated thence to the southern portion of the continent. This movement could not have taken place in the Miocene period, as the Isthmus of Darien was then submerged; but near the close of the Tertiary, the elevation of this region left a much broader strip

of land than now exists there, and over this, the Edentates and other mammals made their way, perhaps urged on by the increasing cold of the glacial winters. The evidence to-day is strongly in favor of such a southern migration. This, however, leaves the Old World Edentates, fossil and recent, unaccounted for; but I believe the solution of this problem is essentially the same, namely: a migration from North America. The Miocene representatives of this group, which I have recently obtained in Oregon, are older than any known in Europe, and, strangely enough, are more like the latter and the existing African types than like any of our living species. If, now, we bear in mind that an elevation of only 180 feet would close Behring's Straits, and give a road thirty miles wide from America to Asia, we can easily see how this migration might have taken place. That such a Tertiary bridge did exist, we have much independent testimony, and the known facts all point to extensive migrations of animals over it.

The *Cetacea* are connected with the marine Carnivores through the genus *Zeuglodon*, as Huxley has shown, and the points of resemblance are so marked that the affinity cannot be doubted. That the connection was a direct one, however, is hardly probable, since the diminutive brain, large number of simple teeth, and reduced limbs in the Whales, all indicate them to be an old type, which doubtless branched off from the more primitive stock leading to the Carnivores. Our American extinct Cetaceans, when carefully investigated, promise to throw much light upon the pedigree of these strange mammals. As most of the known forms were probably marine, their distribution is of little service in determining their origin.

That the Sirenians are allied to the Ungulates, is now generally admitted by anatomists, and the separation of the existing species in distant localities suggests that they are the remnants of an extensive group, once widely distributed. The large number of teeth in some forms, the reduced limbs and other characters, point back to an ancestry near that of the earliest ungulates. The gradual loss of teeth in the specialized members of this group, and in the Cetaceans, is quite parallel with the same change in Edentates, as well as in Pterodactyles and Birds.

The Ungulates are so distinct from other groups that they must be one of the oldest natural divisions of mammals, and they prob-

ably originated from some herbivorous marsupial. Their large size, and great numbers during Tertiary and Post-tertiary time, render them most valuable in tracing migrations induced by climate, as well as in showing the changes of structure which such a contest for existence may produce.

In the review of the extinct Ungulates, I have endeavored to show that quite a number of genera usually supposed to belong originally to the Old World are in reality true American types. Among these were the Horse, Rhinoceros, and Tapir, all the existing odd-toed Ungulates, and besides these the Camel, Pig, and Deer. All these, I believe, and many others, went to Asia from our North West Coast. It must, for the present, remain an open question whether we may not fairly claim the *Bovidæ*, and even the *Proboscidea*, since both occur in our strata at about the same horizon as on the other continent. On this point there is some confusion, at least in names. The Himalayan deposits called Upper Miocene, and so rich in Proboscidians, indicate in their entire fauna that they are more recent than our Niobrara River beds, which, for apparently good reasons, we regard as Lower Pliocene. The latter appear to be about the same horizon as the Pikermi deposits in Greece, also regarded as Miocene. Believing, however, that we have here a more complete Tertiary series, and a better standard for comparison of faunas, I have preferred to retain the names already applied to our divisions, until the strata of the two continents are more satisfactorily coördinated.

The extinct Rodents, Bats, and Insectivores of America, although offering many suggestive hints as to their relationship with other groups, and their various migrations, cannot now be fully discussed. There is little doubt, however, that the Rodents are a New World type, and, according to present evidence, they probably had their origin in North America. The resemblance in so many respects of this order to the Proboscidians is a striking fact, not yet explained by the imperfectly known genealogy of either group.

The Carnivores, too, I must pass by, except to call attention to a few special forms which accompanied the migrations of other groups. One of these is *Machairodus*, the saber-toothed Tiger, which flourished in our Miocene and Pliocene, and followed the huge Edentates to South America, and the Ungulates across Asia to Europe. With this genus went *Hyænodon*, and some typical

Wolves and Cats, but the Bears came the other way with the Antelopes. That the Gazelle, Giraffe, Hippopotamus, Hyæna and other African types, once abundant in Asia, did not come, is doubtless because the Miocene bridge was submerged before they reached it.

The Edentates, in their southern migration, were probably accompanied by the Horse, Tapir and Rhinoceros, although no remains of the last have yet been found south of Mexico. The Mastodon, Elephant, Llama, Deer, Peccary, and other mammals, followed the same path. Why the Mastodon, Elephant, Rhinoceros, and especially the Horse, should have been selected with the huge Edentates for extinction, and the other Ungulates left, is at present a mystery, which their somewhat larger size hardly explains.

The relations of the American Primates, extinct and recent, to those of the other hemisphere, offer an inviting topic, but it is not in my present province to discuss them in their most suggestive phases. As we have here the oldest and most generalized members of the group, so far as now known, we may justly claim America for the birth-place of the order. That the development did not continue here until it culminated in Man, was due to causes which at present we can only surmise, although the genealogy of other surviving groups gives some data towards a solution. Why the old world Apes, when differentiated, did not come to the land of their earlier ancestry, is readily explained by the then intervening oceans, which likewise were a barrier to the return of the Horse and Rhinoceros.

Man, however, came; doubtless first across Behring's Straits; and at his advent became part of our fauna, as a mammal and primate. In these relations alone it is my purpose here to treat him. The evidence, as it stands to-day, although not conclusive, seems to place the first appearance of Man in this country in the Pliocene, and the best proof of this has been found on the Pacific coast. During several visits to that region, many facts were brought to my knowledge which render this more than probable. Man at this time was a savage, and was doubtless forced by the great volcanic outbreaks to continue his migration. This was at first to the south, since mountain chains were barriers on the east. As the native Horses of America were now all extinct, and as the early man did not bring the old world animal with him, his migrations were slow. I believe, moreover, that his slow progress

towards civilization was in no small degree due to this same cause, the absence of the Horse.

It is far from my intention to add to the many theories extant in regard to the early civilizations in this country, and their connections with the primitive inhabitants, or the later Indians, but two or three facts have recently come to my knowledge which I think worth mentioning in this connection. On the Columbia River, I have found evidence of the former existence of inhabitants much superior to the Indians at present there, and of which no tradition remains. Among many stone carvings which I saw there, were a number of heads which so strongly resemble those of Apes, that the likeness at once suggests itself. Whence came these sculptures, and by whom were they made? Another fact that has interested me very much is the strong resemblance between the skulls of the typical Mound-builders of the Mississippi Valley and those of the Pueblo Indians. I had long been familiar with the former, and when I recently saw the latter, it required the positive assurance of a friend who had himself collected them in New Mexico, to convince me that they were not from the mounds. A third fact, and I leave Man to the Archæologists, on whose province I am even now trenching. In a large collection of Mound-builders' pottery, over a thousand specimens, which I have recently examined with some care, I found many pieces of elaborate workmanship so nearly like the ancient water-jars from Peru, that no one could fairly doubt that some intercourse had taken place between the widely separated people that made them.

The oldest known remains of Man on this continent differ in no important characters from the bones of the typical Indian, although in some minor details they indicate a much more primitive race. These early remains, some of which are true fossils, resemble much more closely the corresponding parts of the highest Old World Apes, than do the latter our Tertiary Primates, or even the recent American Monkeys. Various living and fossil forms of old world Primates fill up essentially the latter gap. The lesser gap between the primitive Man of America and the Anthropoid Apes is partially closed by still lower forms of men, and doubtless also by higher Apes, now extinct. Analogy, and many facts as well, indicate that this gap was smaller in the past. It certainly is becoming wider now with every generation, for the lowest races of men will soon become extinct, like the Tasmanians, and the highest Apes

cannot long survive. Hence the intermediate forms of the past, if any there were, become of still greater importance. For such missing links, we must look to the caves and the later Tertiary of Africa, which I regard as now the most promising field for exploration in the Old World. America, even in the Tropics, can promise no such inducements to ambitious explorers. We have, however, an equally important field, if less attractive, in the Cretaceous Mammals, which must have left their remains somewhere on this continent. In these two directions, as I believe, lie the most important future discoveries in Palæontology.

As a cause for many changes of structure in mammals during the Tertiary and Post-tertiary, I regard, as the most potent, *Natural Selection*, in the broad sense in which that term is now used by American evolutionists. Under this head, I include not merely a Malthusian struggle for life among the animals themselves, but the equally important contest with the elements, and all surrounding nature. By changes in the environment, migrations are enforced, slowly in some cases, rapidly in others, and with change of locality must come adaptation to new conditions, or extinction. The life-history of Tertiary mammals illustrates this principle at every stage, and no other explanation meets the facts.

The real progress of mammalian life in America, from the beginning of the Tertiary to the present, is well illustrated by the Brain-growth, in which we have the key to many other changes. The earliest known Tertiary mammals all had very small brains, and in some forms this organ was proportionally less than in certain Reptiles. There was a gradual increase in the size of the brain during this period, and it is interesting to find that this growth was mainly confined to the cerebral hemispheres, or higher portion of the brain. In most groups of mammals, the brain has gradually become more convoluted, and thus increased in quality, as well as quantity. In some, also, the cerebellum, and olfactory lobes, the lower parts of the brain, have even diminished in size. In the long struggle for existence during Tertiary time, the big brains won, then as now; and the increasing power thus gained rendered useless many structures inherited from primitive ancestors, but no longer adapted to new conditions.

Another of the interesting changes in mammals during Tertiary time was in the teeth, which were gradually modified with other

parts of the structure. The primitive form of tooth was clearly a cone, and all others are derived from this. All classes of vertebrates below mammals, namely, Fishes, Amphibians, Reptiles, and Birds, have conical teeth, if any, or some simple modification of this form. The Edentates and Cetaceans with teeth retain this type, except the Zeuglodonts, which approach the dentition of aquatic Carnivores. In the higher mammals, the incisors and canines retain the conical shape, and the premolars have only in part been transformed. The latter gradually change to the more complicated molar pattern, and hence are not reduced molars, but transition forms from the cone to more complex types. Most of the early Tertiary mammals had forty-four teeth, and in the oldest forms the premolars were all unlike the molars; while the crowns were short, covered with enamel, and without cement. Each stage of progress in the differentiation of the animal was, as a rule, marked by a change in the teeth; one of the most common being the transfer, in form at least, of a premolar to the molar series, and a gradual lengthening of the crown. Hence, it is often easy to decide from a fragment of a jaw, to what horizon of the Tertiary it belongs. The fossil Horses of this period, for example, gained a grinding tooth, for each toe they lost, one in each epoch. In the single-toed existing horses, all the premolars are like the molars, and the process is at an end. Other dental transformations are of equal interest, but this illustration must suffice.

The changes in the limbs and feet of mammals during the same period were quite as marked. The foot of the primitive mammal was doubtless plantigrade, and certainly five-toed. Many of the early Tertiary forms show this feature, which is still seen in some existing forms. This generalized foot became modified by a gradual loss of the outer toes, and increase in size of the central ones; the reduction proceeding according to systematic methods, differing in each group. Corresponding changes took place in the limb bones. One result was a great increase in speed, as the power was applied so as to act only in the plane of motion. The best effect of this specialization is seen to-day in the Horse and Antelope, each representing a distinct group of Ungulates, with five-toed ancestors.

If the history of American Mammals, as I have briefly sketched it, seems as a whole incomplete, and unsatisfactory, we must

remember that the genealogical tree of this class has its trunk and larger limbs concealed beneath the *débris* of Mesozoic time, while its roots doubtless strike so deeply into the Paleozoic that for the present they are lost. A decade or two hence, we shall probably know something of the mammalian fauna of the Cretaceous, and the earlier lineage of our existing mammals can then be traced with more certainty.

The results I have presented to you are mainly derived from personal observation; and since a large part of the higher vertebrate remains found in this country have passed through my hands, I am willing to assume full responsibility for my presentation of the subject.

For our present knowledge of the extinct Mammals, Birds and Reptiles of North America, science is especially indebted to Leidy, whose careful, conscientious work has laid a secure foundation for our vertebrate palæontology. The energy of Cope has brought to notice many strange forms, and greatly enlarged our literature. Agassiz, Owen, Wyman, Baird, Hitchcock, Deane, Emmons, Lea, Allen, Gibbes, Jefferson, DeKay, and Harlan, deserve honorable mention in the history of this branch of science. The South America extinct vertebrates have been described by Lund, Owen, Burmeister, Gervais, Huxley, Flower, Desmarest, Aymard, Pictet, and Nodot. Darwin and Wallace have likewise contributed valuable information on this subject, as they have on nearly all forms of life.

In this long history of ancient life, I have said nothing of what Life itself is. And for the best of reasons, because I know nothing. Here at present our ignorance is dense, and yet we need not despair. Light, Heat, Electricity, and Magnetism, Chemical Affinity, and Motion, are now considered different forms of the same force; and the opinion is rapidly gaining ground that Life, or vital force, is only another phase of the same power. Possibly the great mystery of Life may thus be solved, but whether it be or not, a true faith in Science knows no limit to its search for Truth.

PAPERS READ.

Note upon the History and Value of the Term Hudson River Group in American Geological Nomenclature. By James Hall, of Albany, N. Y.

During the past year my attention has been especially directed to a note written by me and published in the Geological Report of Wisconsin, in the early part of 1862, in reference to the Hudson River Group.

In this note I had accepted the determinations made by the Geological Survey of Canada, regarding the extension of the older rocks of the Champlain and Hudson valleys, marked by the presence of a primordial fauna, accepting at the time the suggestion that the few known fossils of the "Second Fauna" in the Hudson River shales, were contained in some outliers of insignificant extent embraced within the folds of the older rocks, or resting upon the primordial beds which formed the fundamental rocks of the valley. Primordial forms of Trilobites were known to occur in the shales of Georgia, Vt., and in Washington county, N. Y. The Graptolites of Norman's Kill and other localities had been referred by Mr. Billings to the primordial fauna; a similar view having been previously advanced by Dr. Emmons, who had included many of these species in his Taconic system, and had, moreover, extended the term Taconic to the shales of the Hudson valley. The Graptolites of the Canadian Survey, which had been placed in my hand for description and illustration, embraced collections from Point Levis, and other localities on the St. Lawrence below Quebec. Among these were a considerable number of species identical with those of the shales of the Hudson River valley; and it was asserted that all were of the same geological age as the Point Levis shales.[1]

[1] The correction of this reference of the Graptolites was not made until considerable time afterwards, when, having satisfied myself of the true relations of the Hudson River Graptolite beds, I protested against including these forms with those of the slates of Point Levis; and they were omitted from the Decade, after having been figured.

Admitting the facts as presented, there seemed, therefore, at that time, no escape from the conclusion that we had been in error in referring our Graptolite slates to the "Second Fauna." These slates are a marked feature in the rocks of the Hudson Valley; and occur at numerous localities over an extent of more than fifty miles along the river valley, and evidently constitute a very considerable part of the great mass of the rock formation. The conclusion was, therefore, unavoidable, that if these graptolite slates were to be regarded as Primordial, we had small evidence to the contrary in the two or three limited areas which had furnished a few fossils of the "Second Fauna."

Not only from the publications on this subject, did I base the opinions expressed in the above mentioned note, but also the numerous letters of Sir William Logan, who, reviewing his earlier position relative to the Hudson River Group, now abandoned the views which he strenuously maintained two years previously (1859), and showed, by his method of interpretation, that the whole series was of primordial age; and that we had hitherto been in error as to our views of the structure.

Under the pressure of the necessity of publishing the Geological Report of Wisconsin, which was mostly printed in 1861 — with no opportunity for testing the question in the field, and wishing to avoid the perpetuation of an error, I dropped the term Hudson River, as applied to the green shales and calcareous bands above the Trenton limestone, and wrote the explanatory note which the circumstances seemed to render necessary; and which has unfortunately been allowed to remain too long unexplained.

Subsequently, Sir William and myself undertook some investigations along the Hudson River and the adjacent counties on the east, which led to a clear recognition of the slates and sandstones of the Hudson River Group on both sides of the river, as originally designated and limited in signification by the New York geologists, and constituting by itself the entire mass of the formation. On the West bank of the river this Group continues uninterruptedly from Saratoga county to Kingston in Ulster county; and on the east side of the river, is clearly defined along the valley, with a width of from one to several miles, varying and irregular in outline, through the counties of Washington, Rensselaer and Columbia, its eastern limit approaching the river near Rhinebeck.

A farther careful study of the materials collected showed conclusively that, within the limits indicated, all the fossils were of the "Second Fauna." Many of the species of Graptolites, so abundant in certain localities of the disturbed and partially altered shales, were also found in the shales and sandstones which gradually assumed an undisturbed and unaltered condition within a few miles west of the river, extending thence through the Mohawk valley, where they rest conformably upon the limestones of the Trenton Group.

Limited on the east by older rocks, the formation extends in unbroken continuity from the Hudson, through the Mohawk valley, outcropping on one or both sides of the river, and, beyond Little Falls expanding over a wide area in Oneida, Lewis, Oswego and Jefferson counties. Here, interrupted by Lake Ontario, its extension may be taken up on the north shore of the lake, and traced throughout the Upper Peninsula; and thence upon the islands of Lake Huron, as I have long ago shown; the formation becoming more argillaceous and calcareous in its western extension, forming the green shale and limestone beds of Big and Little Bay de Noquets and of Green Bay; everywhere resting on the Trenton limestone, and surmounted by the Medina sandstone, the Clinton and Niagara Groups.[2]

The formation everywhere contains the same species of fossils, with a largely increasing number of individuals and of species as we go westward. The forms known in the Hudson and Mohawk valleys, are found in these rocks near Toronto and throughout the western peninsula; in the islands of Lake Huron; at the Baiès de Noquets, Green Bay and elsewhere. The physical limits of the formation are the same by whatever name it may be known in different portions of its extent; and its fossil species being everywhere identical, the designation should be the same throughout.

From the earliest teachings in American Geology, these disturbed and partially altered rocks of the Hudson valley have been a subject of discussion. From the first, their relations and relative age have been misinterpreted, owing to the fact that not only the rocks in the immediate valley of the Hudson, but also those be-

[2] We have representations of the Medina sandstone and Clinton group on the shores of Green Bay; and of the Clinton group elsewhere in Wisconsin.

tween the river and the eastern limit of the State, were treated as a single group or system of rocks, and belonging to one geological age, thus creating confusion in whatever aspect they were regarded. These were the Transition Rocks of Eaton, and considered by him as the oldest fossiliferous rocks of the country, and older than those of similar character in the Mohawk valley and westward. They included the Argillite; the First Graywacke, embracing the Millstone Grit, Rubble, etc.; the Sparry limerock, Calciferous sandrock, and Metalliferous limestone,— the latter being the Trenton limestone, indicated by Eaton as the upper limit of the Transition Series. The second Graywacke included the unaltered shales and shaly sandstones above the Trenton limestone in the Mohawk valley, and of Oswego county; together with all those subsequently termed Utica slate; Herkimer slate, shales and sandstones of Salmon River and Pulaski; the Loraine shales, etc.

At a later period, in the Geological Survey of Pennsylvania, the belt of rocks between the eastern limit of the State and the Hudson River, and also along the west side of the Hudson, was included in the Series No. III of Prof. Rogers. Subsequently, it was designated by the New York geologists, the Hudson River Group.

Up to the time of the near completion of field work of the Geological Survey of New York, no serious question had been raised regarding a separation of the rocks of the Hudson valley from those forming the belt of country on the east; and it now became necessary to make some designation in accordance with the plan adopted, of giving local names to geological formations. Prof. Mather, whose district embraced the counties of Washington, Saratoga and Schenectady, and the whole extent of the Hudson valley, had clearly traced the formations of this valley along the Mohawk to their undisturbed position in Schenectady and Montgomery counties; and his arguments in favor of the term Hudson River Group were accepted, and the name adopted.[3]

The identity of the formations already enumerated, in the central and northwestern parts of the State, with those of the Mohawk valley at Cohoes and Schenectady, and with those of the Hudson Valley near Albany, Hudson, and numerous other localities, was considered well established; both by direct continuity

[3] These arguments are summarized by Prof. Mather in his final Report, under the head of Geology of Albany, Schenectady and Saratoga counties. Especially, see pp. 377 and 378. These views have been fully confirmed by subsequent investigations.

on the west side of the river, where the superposition was apparent, and by the fossil contents so far as known; and the term Hudson River Group was accepted for the whole.

At that time no question had been raised in regard to the age of the great mass of metamorphic shales and sandstones to the eastward. There was no knowledge of their fossil contents, and they were supposed to be only a more extremely metamorphosed condition of the formation. We now know approximately the limits between the newer and the older formations; and there is no longer any question that the newer series, or the rocks above the Trenton limestone, do occupy both sides of the Hudson River for nearly one hundred miles, and continue along the valley many miles farther toward Lake Champlain.

The term Hudson River Group has therefore a definite signification, from absolute knowledge of superposition and fossil contents. The error lay in extending the term to rocks on the eastward at a time when their fossil contents had not been studied, and were in fact unknown, and their geological position had not been determined by critical examination.

Within a few years the term Cincinnati Group has been proposed and applied to the rocks termed Blue limestone and Marls in the original Geological Survey of Ohio; the same which form the great exposure along the line of the Cincinnati axis. These rocks are of the same age and hold the same geological position, between the Trenton limestone below and the Clinton or Niagara group above, as the rocks of the Hudson River Group in the original signification of the term.

From examinations made in 1841[4] I gave the evidence of certain fossils, and my reasons for identifying this formation in Ohio, Kentucky and Indiana, with the Hudson River Group of New York. I have briefly stated these facts in my Report on the "Geological Survey of New York. Fourth District." In Foster & Whitney's "Report upon the Lake Superior Land District,"[5] I have shown, as I think very clearly, the relations of the Hudson River Group of New York, with the calcareous shales with limestone bands, on Little Bay de Noquet and the peninsula between the Little and Big Bay de Noquet; and also the occurrence of the same beds on the east

[4] Published in the *Transactions of the Association of American Geologists and Naturalists*, 1843.

[5] Vol. II, pp. 148–151.

side of Green Bay; and I have also shown the relations of these rocks with those of the southwestern localities.

The evidence and the arguments adduced by me in 1841, 1843, 1850, and again in 1858,[6] have been fortified by additional observations in later years. The shales and impure sandstones, in disturbed condition along the Hudson valley, are identical with those nearly horizontal and unchanged a few miles to the westward, and continuing throughout the extent of New York and Canada West, with a gradual attenuation, from the cessation of coarser deposits and increase of calcareous matter, until they become what we find them in Michigan and Wisconsin; whence they have been traced into Illinois and Iowa; while the identity of these with the formations in Ohio, Indiana and Kentucky, has been clearly determined and fully acknowledged. The term Hudson River Group had therefore been sufficiently defined. The facts which had sustained it remain unchanged. It has been accepted in Geological Nomenclature, and it is incorporated in all our publications. We cannot, now, apply the term Cincinnati, or any other name, to the shales and sandstones which exist in great development along the Hudson River, extending thence to the Mohawk and its tributaries, and traced in wide expansion and highly fossiliferous character throughout the northwestern counties of New York.

It is true that under the influence of assertions that seemed to prove our original conclusions erroneous, and giving too easy credence to the opinions of others who had full opportunities of investigation, I hastily expressed my belief that the interest of geological science required that the term, Hudson River Group, should be abandoned; in other words, that a name which had been applied to rocks of the second great Palæozoic period, should not be continued in its application to rocks of Primordial age.

The Hudson River Group was originally defined, and many of its characteristic fossils were designated and illustrated, in the Reports of the First, Second and Third Geological Districts of the New York Survey; Dr. Emmons, however, using the term Loraine, while recognizing the formation as of the same age with the shales of the Hudson valley. All the fossils originally cited as typical of the Group are of the Second Fauna. It was at a later period, through Sir William Logan's interpretation of Geological Structure, that some forms of the older Fauna were referred

[6] *Report on the Geological Survey of Iowa.*

to the same group. But because of this mistake, which was easy to be made in a disturbed region of country, no good reason is afforded for abandoning the use of a term by which a well-established group of strata was originally designated and accepted.

THE OLDER ROCKS OF WESTERN NORTH AMERICA. By T. STERRY HUNT, of Boston, Mass.

[ABSTRACT.]

THE author began by calling attention to the great types of crystalline stratified eozoic rocks which he has recognized in the eastern part of the continent, and in Europe, and which he has endeavored to show, constitute distinct groups, well marked, both lithologically and geognostically. He then gave some conclusions drawn from observations made by himself at a few points among the crystalline rocks during a late journey in the West. His examinations of these among the Rocky Mountains were made in the Sangre de Christo range, near Garland; and in the Front or Colorado range at the Ute pass and Glen Eyrie, and also along Clear Creek cañon and about Georgetown. In all of these localities he found gneissic rocks, frequently granitoid, often hornblendic, but scarcely micaceous, and apparently identical with the Laurentian series of the East. He referred to the published observations of the late Mr. Marvine in Hayden's report for 1873, who had carefully studied these rocks in the Colorado range, and who compared them to the Laurentian, and he agreed with Mr. Marvine in regarding as indigenous the red granitoid rocks in the region of the Ute pass. Similar granitoid rocks at and near Sherman, on the Union Pacific railroad, are also, according to the author, probably of the same nature. He referred in this connection to the area of labradorite rocks having the character of the Norian series, found in the Rocky Mountain region, in Wyoming, but known to the speaker only through specimens.

The rocks of the Wahsatch range, as seen in the Devil's Gate on the Weber River, are Laurentian, to which series are to be referred also the crystalline stratified rocks found in the same range further south, in the upper part of the Little Cottonwood cañon.

Here, among loose blocks of the gneiss, are found occasional masses of coarsely crystalline limestone with mica, and others of a peculiar type of pyroxenic rock which accompanies similar limestones in the Laurentian series. The crystalline rocks in the lower part of the same cañon are, however, well marked exotic or eruptive granites.

Eruptive granites are found in California, where they abound among the foot-hills of the Sierras, in Placer and Nevada counties. The crystalline schists observed by the speaker in these counties, and in Amador county, are Huronian, and have all the characters of the Huronian series as seen in the eastern regions of North America, and of the *pietri verdi* of the Alps. To this horizon are also to be referred the similar crystalline rocks of the Coast range of California, as seen near San Francisco and San Jose. The auriferous veins which, in the Rocky Mountains, intersect the Laurentian gneisses, are found in the Sierras alike in the Huronian schists and in the eruptive granites, which probably penetrate the Huronian series.

GEOLOGY AND TOPOGRAPHY OF THE OIL REGION OF TENNESSEE, WITH SOME ACCOUNT OF THE OIL SPRINGS AND WELLS. By J. B. KILLEBREW, of Nashville, Tenn.

THE oil territory of Tennessee occupies the extreme southern end of the great oil belt which extends in a southwesterly direction from Ontario, Canada, through New York, Pennsylvania, West Virginia, Kentucky, and, as far as now known, terminates in Tennessee. The belt widens at both extremities, bearing to the westward in Canada around Lake Erie, and spreading out laterally in Tennessee, so as to comprise Dickson and Hickman counties, lying west of Nashville. The following counties are included, or are supposed to be included, in the oil region of Tennessee, namely: Overton, Clay, Putnam, Fentress, Jackson, Trousdale, Sumner, Davidson, Dickson, and Hickman. In all these some petroleum has been found; but by far the most numerous indications have been met with in the counties of Overton, Putnam, Clay, and Fentress, all of which lie at the western foot, and even include a part of the Cumberland table-land. The oil exudations are found

mostly within the limits of a belt lying at the western base of the Cumberland table-land, which belt is about eighteen miles wide, and has a northeasterly and southwesterly direction.

Geology.—The oil region in Tennessee belongs mainly to that natural division of the State called the Highland Rim, which surrounds, like the rim of a plate, the great silurian limestone basin in which Nashville is situated. For the most part the formations of the oil region pertain to the Sub-Carboniferous, though the streams have cut deep channels through this formation and the Devonian black shale to the Cincinnati or Nashville group of the Lower Silurian. The Devonian age in the Tennessee oil region, unlike that of Pennsylvania, has but one representative, and that corresponds to the Hamilton black shale of New York. The Coniferous, Marcellus, Portage, Chemung and Catskill are all wanting; also the whole of the Upper Silurian formations. The Upper Silurian appears west of Nashville, and to a limited extent in the western part of Sumner county, northeast of Nashville, where the Meniscus gray limestone of the Niagara epoch is present in considerable volume—estimated at one hundred and twenty feet in thickness. It thins out farther eastward, and totally disappears in the counties constituting the oil centre. The Portage group, in New York and Pennsylvania, consists of shales and laminated sandstones, and has a thickness of about seventeen hundred feet.

The Chemung epoch has the same general lithological character, and in these two members of the Devonian age most of the oil product of Pennsylvania is stored. In Overton county in Tennessee in which the greatest number of oil-springs occur, there is a great variety of geological formations. The coal measures cap the highest point in the eastern parts of the county and are also met with near the crests of such isolated peaks as Pilot Knob and Alpine mountain, both outliers of the Cumberland tableland, but separated from it by profoundly eroded chasms. The Sub-Carboniferous, consisting of two groups—the Mountain Limestone and Silicious group—has a wide-spread development, the Mountain Limestone, about four hundred feet thick, occurring in limited areas, forming benches on the slope of the Cumberland table-land and its outliers, and also appearing on the side of the terrace lands, which occupy a considerable part of the county. The Silicious group covers fully three-fourths of the county, and is the foundation for the clay uplands. This group has two numbers: First, the

Lithostrotion or coral beds; second, the Lower Silicious or Protean bed, which underlies the first. The Lithostrotion or coral bed covers extensive areas in the oil region, and may always be known by the presence of a fossil coral (*Lithostrotion canadense*) resembling a "petrified hornet's nest." This formation is also always characterized by the presence of sink-holes, showing the existence of underground channels. The town of Livingston is built upon a bed of this coral. This bed is about two hundred feet thick, and its top layers consist often of heavy-bedded, grayish limestone, known as the St. Louis limestone. Some of it is highly crystalline, and makes a respectable marble. The Lower Silicious or Protean bed, about two hundred and seventy feet thick, covers all the region around Spring creek, at which place the greatest quantity of oil has been obtained; also, the undulating lands south of Livingston, and the flat lands on the west. It displays itself in frequent depressions in the north and northwest portions of the oil belt. It takes numerous forms; sometimes its top-layers are a fine-grained, exceedingly porous, yellowish sandstone. This often overlies a limestone, bluish fetid, crinoidal. Oftentimes for this limestone is substituted another layer, exceedingly silicious, filled with nodules of chert, or interstratified with thin and thick layers of the same material. These cherty layers sometimes displace the calcareous material altogether. Again, the Keokuk shales, hard, bluish, thin and calcareous, usurp the place of the sandstone, grayish limestone and cherty layers, and form a continuous shale-bed two hundred and fifty feet thick. This is the case on Eagle creek, in the northeastern part of the county. The bluffs below Waterloo falls, on Spring creek, are composed of a great thickness of crinoidal limestone, in which crinoidal buttons and stems form a considerable part of the mass. The same is true with some of the bluffs on Obeys river. Above Waterloo falls the silicious limestone prevails.

Immediately below the Sub-Carboniferous comes the Devonian black shale, highly charged with petroleum and fissured by numerous vertical crevices, which make it resemble, where exposed, a tessellated floor. It is seldom met with as a top formation. A few limited areas, where it appears as such, may be found near the mouth of Eagle creek and in the beds of some of the streams as they approach Obeys and Cumberland rivers. It is, however, a very persistent formation, and may always be found throughout

the State in its proper geological horizon. Its usual thickness in the Tennessee oil region is from twenty-six to thirty-five feet.

The Cincinnati and Nashville group of the Lower Silurian presents itself in the beds or inclosing banks of the principal streams as they approach the Cumberland river.

On Spring creek the rocks of the Cincinnati group come to the surface below Waterloo falls: on Roaring River, below Crawford's mill, and on Obeys river, just below the mouth of Franklin creek. The following section, taken in the region around the oil wells at Spring creek by Dr. Safford, but since corrected by myself to correspond with the result of the borings, will serve to illustrate the geological, lithological and paleontological features of the strata at this place. The section given is really a combination of two sections, so as to include both the lower coal-measures and the Sub-Carboniferous formations:

Coal-measures, sandstones and shales . . .	250 feet
Mountain limestone heavy bedded, filled with pentremites; some of the layers argillaceous	432 feet
Lithostrotion or upper silicious limestone, containing Lithostrotion canadense	203 feet
Protean or lower Silurian, flinty layers and fetid limestone	269 feet
Black shale	38 feet

Topography.—As might be inferred from the great diversity of geological formations, the topographical features are striking, and show variety in an eminent degree. There are rugged heights, rolling plains, level plateaus, rocky gorges, deep sunk valleys and coves, sheltered between the massive walls of towering hills. The Cumberland table-land has scalloped edges, displaying very ragged contours, steep escarpments, sloping sides, roughened by shapeless boulders. The sides of the mountain are furrowed by many a stream. Chasms, great and terrible, profound in their depths, and striking in their suddenness, form one of the principal features of the western mountain side; spurs shoot out for many a mile into lower plains. Many of these are dissected by transverse gorges, leaving isolated peaks nearly or quite as high as the

Cumberland mountain itself. The top of the mountain has all the characteristics peculiar to this division of the State; that is to say, level areas on the summit, a thin soil resting upon a conglomerate sandstone, from the crumbling down of which it has been derived, scraggy timber, open vistas, freestone and chalybeate-water. Two or three seams of good coal are usually found under the cap of conglomerate rocks, interstratified with shales and sandstones. The soil of the mountain is adapted to the growth of apples, Irish potatoes and garden vegetables generally. The land is thinly wooded, the surface covered usually in summer with a luxuriant growth of native grasses and pea vines, and furnishing a large amount of highway pasturage. But few inhabitants are found here, and this part of the oil region is almost as wild as when the Indian roamed in all his fearless independence through its silent forests.

Upon this mountain there is every condition of health. There is a life-giving property in the atmosphere that imparts elasticity to the frame, giving joy to the heart and animation to the soul. The mind and body receive a new vitality by being bathed in this pure mountain air, which produces an exhilaration of spirits beyond that of drugs. Consumption never occurs here. The time is not now but it will come when the edges of this mountain will be covered with the palaces of the rich and the cottages of the poor, who will come to enjoy the perpetual delight of breathing the mountain air.

The main features of the oil belt are easily described. It may be represented by a nearly level plain, cut from northeast to southwest by a valley half a mile wide, and four hundred feet deep. This is the valley of the Cumberland river. Opening into the Cumberland valley on the eastern side is the long winding valley of Obeys river, with a general direction from east to west. A number of smaller streams, with valleys of their own extending outward at nearly right angles to the river, with their ramifications, cut up this plain into innumerable winding spurs pointing to the river like the bent or zigzagged teeth of a saw. These ramifications run back among the highlands, gently rising toward their head. These valleys are always skirted by hills ranging from one hundred to four hundred feet in height. Many of the creeks are short and inclosed always by high bordering ridges. So numerous are these breaks that some have doubted that they have been produced by erosion, and think that they mark the course of the great cracks

formed in the underlying rocks as they were hardening or shrinking, or yielding to the forces of subsidence and upheavals during the unstable period of geological eras. With this opinion I cannot agree. The rocks are approximately horizontal. A few gentle curves in the strata are met with here and there, forming long anticlinals and synclinals, but at no place do these depressions correspond with the profoundly eroded surface. Indeed, it often occurs that no disturbance of strata is exhibited where the gorges are deepest. At some few places there are signs of disturbance. Near the mouth of Ashburn creek the strata all dip northeasterly, at an angle of some five degrees, and fissures appear in the Nashville limestone, from which petroleum issues.

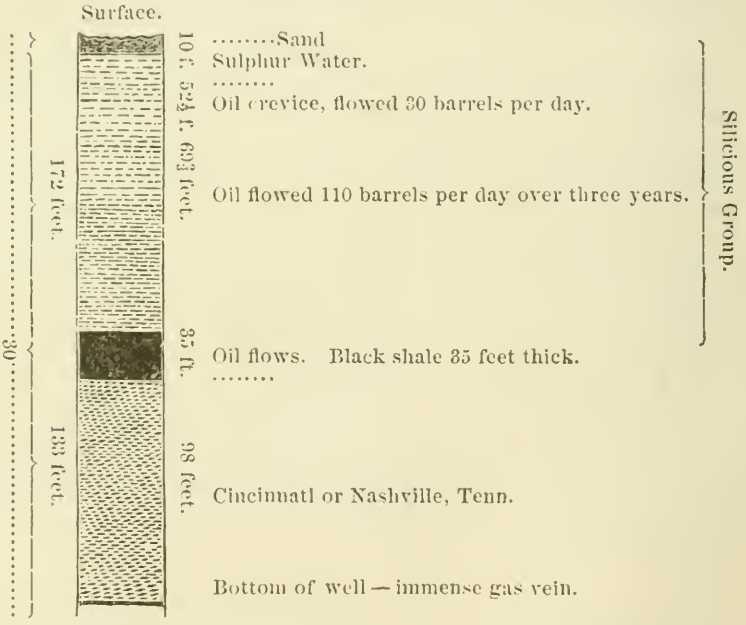
Oil Springs and Wells.—Having given the general geological features and topographical outlines of the central oil region, it remains to give a few general facts in reference to the oil-wells which have been bored and the oil-springs which are found in numerous localities in this oil region. On Spring creek the productive wells were sunk near the eastern margin of that stream, in a low, flat place, inclined to be swampy. An expanse of rolling land spreads out eastwardly for about three miles. On the southeast and northeast, spurs rise to the height of one hundred feet or more, showing on their sides thick ledges of the St. Louis limestone. Beyond these spurs, on the east, the gray outlines of the Cumberland table-land appear, giving grandeur and beauty to the scene. This oil-valley is three and a half miles long by three-quarters of a mile wide. Its elevation above the sea is about nine hundred and sixty feet. All the wells bored at this place were commenced about one hundred and seventy-five feet above the black shale. The following is a section of the Jackson well, the deepest one bored in the valley:

Alluvial soil	7 to 9 feet.
Flinty limestone	165 feet.
Black shale	35 feet.
Nashville rocks	293 feet.
Total	530 feet.

Eleven wells were bored within an area of 150 feet. Oil was found in two or more zones, one at from 19 to 26 feet below the

surface, and the other (by far the most productive zone), from 51 to 69 feet. Probably 20,000 barrels of oil flowed from two wells, some others yielding a less quantity. The following is a brief record of the wells: Newman well, at 26 feet, 2600 barrels; at 51 feet 7 inches, an immense flow—supposed to be many thousand barrels. Jackson well, no oil; sunk 530 feet. Douglass well, at 22 feet, 40 barrels per day; supply shut off when the big strike was made in Newman well; at 69 feet 8 inches 110 barrels per day were afterward taken out with strong salt water. Hoosier well, at 52 feet 6 inches 30 barrels per day; at 69 feet 8 inches

SECTION OF THE HOOSIER WELL, NO. 1, SPRING CREEK.



110 barrels per day for over three years. Hoosier well No. 2, at 55½ feet, 25 barrels per day. Hoosier well No. 3, at 53½ feet, 160 barrels oil per day. Five other wells were bored without striking oil. Out of the eleven wells bored, five were productive and six were dry holes.

Three facts stand out quite prominently in the records of the borings on Spring creek: First, the area of the oil was very limited. Second, all the oil was obtained from the crevices or

cavities of a hard silicious rock one hundred and twelve to one hundred and fifty-five feet above the black shale. Third, the subterraneous crevices or caverns had for the most part no connection with one another, but were distinct, each one holding its treasured supply of oil, and oftentimes occurring one immediately above the other.

Passing now in a northerly direction through Livingston and beyond some ten miles, on the waters of West Fork, we enter upon an oil region only known by its leakage. The West Fork hews its way down through the St. Louis limestone, Waverly sandstone and Keokuk shales. The bluffs rise for the most part abruptly from the water's edge, with occasionally narrow strips of bottom-land. The stream is one of great rapidity. Koger's farm, upon which the oil indications are most numerous, is within four miles of the mouth of West Fork. The bluffs on the river show a succession of wrinkles, and the limestones are soft and much eroded by atmospheric and pluvial agencies. The hills are oftentimes sloping and covered by a coating of unctuous clay. The following section was taken on the east side of the stream, just above where the oil indications are most numerous:

SECTION AT KOGER'S FARM ON WEST FORK.

On high points above, back from the stream, sandstone, fine-grained and buff colored .	20 feet.
Buff colored sandy limestone	6 feet.
Gray crystalline limestone	79 feet.
Calcareous shales, blue and gray	37 feet.
Thin beds of bluish and buff colored limestones, inclined to be shaly—some few sandy layers	113 feet.
Sand and alluvium	6 feet.

This last is a small bottom about 115 feet wide running up and down the stream. The sands of this bottom are thoroughly saturated with oil. By sinking a hole anywhere in this small strip, or in the bed of the stream, petroleum rises to the surface in brownish or bluish disks, which float away on the surface of the stream. The bluish disks are beautiful in their iridescence, displaying in the light all the colors of the rainbow. At this place

many gallons may be collected in a day. The oil-saturated sand extends for the distance of one hundred yards or more.

On the east side of the stream, after ascending the bluff, there is a level plateau extending two miles or more eastward, in the direction of East Fork. The ridge spoken of is made of mountain limestone, capped by the lower sandstone of the coal measures. At a point a little above the Koger farm, where the Livingston and Jameston road crosses West Fork, oil occasionally oozes out from the bank of the stream, and just below are several places where salt water comes from the bluffs leaving a salty incrustation upon the face of the rock. Half a mile below the Koger farm a saw-mill stands upon a short tributary stream, a few yards from West Fork. In blasting out rock, oil was found in the pores and crevices of the rocks. Still lower down the stream, and one mile above its union with East Fork, the mass of slimy mud in the stream is thoroughly saturated with petroleum. By pushing a stick down in this mud gas and petroleum ascend to the surface from the spongy mass. The very atmosphere at this place is redolent of petroleum, and one can scarcely touch the earth for a space of several hundred feet, without having his olfactories offended by the odor of the oil. The formations here agree precisely with those at the Koger farm. The Waverly sandstone appears on the heights above in some greater thickness, and one layer of sandstone a foot thick is found interstratified with the Keokuk slates, which here take the place of the silicious rocks.

Just below the junction of East and West Forks, about three-quarters of a mile, a stream of oil comes out of the bed of Obeys river. This is on the land of James Lacey. When the water is low, the sand taken from this place is so saturated with oil as to make a bright flame. At Goose Neck Bend, up East Fork three miles above its junction with West Fork, there is an oil spring, and several more are reported to exist higher up the stream. One-half mile below Lacey's another spring breaks out near the centre of Obey's river; the oil has been seen here for fifty years. Three miles farther down, near the mouth of Franklin creek, oil is seen coming out of the bed of the river, immediately under a bluff three hundred feet high. The oil oozes out beneath thirty feet of black shale. The rocks above the shale at this point are filled with silicious crinoidal stems in such abundance as almost to make up the mass. The oil here is lighter than that on West Fork and

plays in its rainbow-hued disks upon the surface of the water. Between the mouth of Franklin creek and Lacey's farm the river cuts through the black shales. Franklin creek is in Fentress county, and runs west, emptying into Obeys river. It is about three miles long. One mile above its mouth there is a gravelly bar, which is steeped in petroleum. The pebbles look as though they had been immersed or boiled in petroleum. The oil is above the black shale. The ascent from the mouth of the creek to this place is fifty feet, or more. There are several long sags in the strata here, and greenish and bluish shales are seen in the overlooking bluff. This oil-seep is near the ragged edge of the Cumberland mountain. Near the mouth of Eagle creek there are many indications of oil. Seeps occur at intervals from its mouth for six or eight miles up the stream. Eagle creek rises five miles north of Livingston, flows north and northwest, and enters Obeys river, seven or eight miles below the mouth of West Fork. Its entire length, in a straight line, is about ten or twelve miles. On Trammell's creek, in Sumner county, oil was found at the depth of thirty feet in the black shale. It was a very heavy lubricating oil. In Dickson county, west of Nashville, oil has been found in the Nashville rocks at the depth of five hundred and forty-two feet.

The following conclusions may be deduced from the facts presented. First, that the petroleum in Tennessee is not confined to any particular formation, but finds its storage in the crevices of the silicious rocks of the lower Carboniferous, as on Spring creek; in the black shale, as on Trammell's creek; in the Nashville rocks, as on Eagle creek, at Butler's landing, and in Dickson county, west of Nashville. The springs or natural outlets show a similar range of formations. At Spring creek oil exudes from the alluvial deposits lying above the lower member of the silicious group; on Koger's farm, on the West Fork from alluvium, based upon layers of shaly limestone; on Eagle creek and Franklin creek, from fluviatile deposits, resting on the black shale; on Obeys river, just below the mouth of Franklin creek, from beneath the black shale, and at numerous places from this point down to the mouth of the river, oil bubbles up from the Nashville rocks. Second, the conditions of storage in the Tennessee oil region are not so favorable for the preservation of petroleum as they are in the oil region of Pennsylvania. In Tennessee the oil finds a lodgement only in the crevices of rocks lying above or below the black shale, rarely in

the black shale. The wells will probably be quickly exhausted. There is wanting a porous, absorptive sandstone, surrounded by an impervious formation to prevent leakage. The unusual number of oil springs shows that nature has not provided sufficient storage for her precious products. The remains of organic life, animal and vegetable, disseminated through argillaceous material, constitute in abundance the elements necessary for generating petroleum, but the provisions to prevent waste are inadequate. Owing to the absence of a porous sandstone the oil supply in Tennessee, as has been stated, is collected in fissures, or cavities, which are soon emptied. There will probably be proportionally more wells known as "spouters" in the Tennessee than in the Pennsylvania oil region and fewer durable wells. In the "spouters" the oil is forced up above the surface by gas-pressure.

THREE CONDITIONS ARE NECESSARY ANTECEDENTS TO A PRODUCTIVE OIL REGION.

First—There must be the elements for generating oil or a mother-rock.

Second—There must be an ample store-house, provided either in the interstices of a porous sandstone, which is best, or in cavities in limestone, or fissures in or between other strata.

Third—These store-houses must be sealed up in an impervious formation, but this impervious surrounding must include both the mother or generating-rocks, and the storage rocks, and not come between them.

Petroleum may be generated and lost for want of a suitable reservoir to collect and preserve it; or there may be a reservoir, but no elements existing for its generation; or there may be both of these, but the want of an impervious surrounding may permit the oil to dribble away as fast as formed. All these conditions must coëxist or a productive oil-field is impossible.

The most difficult problem to solve is how the oil is generated, or whence that comes which is found in the cavities of a hard, impervious, flinty rock, which shows no remains of organic life. But one solution presents itself to my mind, and that is, the place now occupied by these cavities may have been filled with drifted organic matter, which has been transmuted into petroleum in Nature's lampless observatory.

GEOLOGY OF THE REGION ABOUT THE HEAD-WATERS OF THE ANDROSCOGGIN RIVER, MAINE. By J. H. HUNTINGTON, of Hanover, N. H.

[ABSTRACT.]

THE speaker referred to some peculiarities in the topography of the region and to those who had written in regard to the geology of northwestern Maine.

The rocks of the area described are referred to the following formations.

I. STRATIFIED GROUPS.

Laurentian.

Gneiss.
Gneiss, containing limestone.

Huronian.

White Mountain gneisses and schists.
Mica schists with staurolite.
Chloritic and whitish argillitic mica schists.
Sandstone schists.
Diabase.
Diorite with serpentine.
Argillitic mica schist with staurolite.
Rangely conglomerates.

Palæozoic.

Wrinkled argillaceous schists, with hard micaceous bands.
Slaty conglomerates.
Calcareous sandstone with fossils.

Cenozoic.

Glacial drift.
Modified drift, including kames, etc.

II. ERUPTIVE ROCKS.

Granite (Conway).
Diorite (micaceous and garnetiferous).
Felsite.

Laurentian.

Gneiss. The area of gneiss is very small and it was seen only on the boundary at the head-waters of the northwest branches of

the Kennebago river. It is a fine-grained rock and the outcrops are so few that the dip could not be well determined. As an intrusive granite and a fine-grained diorite were the only rocks seen in the vicinity, its stratigraphical relations have not been satisfactorily determined, but its resemblance to the Laurentian gneiss in the vicinity of the chain of lakes to the northeast, makes it altogether probable that it is a part of the Upper Laurentian.

Gneiss with limestone. Approaching the Lake region from the east, at the village of Phillips, we find an intrusive granite, which is somewhat coarser than the common Concord granite; it extends a mile east of the village. On Sandy river, where the road crosses the river for the first time above Phillips, we find the intrusive character of the rock clearly shown, as here great masses of schist have been caught in it, and elsewhere the granite appears only as vein-stones in the schist. About two miles above the village, on the north side of the river, there is a fine-grained micaceous gneiss that has intercalated beds of a dark limestone, so pure that at some time it has been burned for lime. The whole breadth of the country occupied by this gneiss does not here exceed a mile, the strata are very irregular in strike and have an inclination of 30° to 50°.

Huronian.

White Mountain gneiss and *schists.* These rocks, which belong to the Montalban series of the New Hampshire Geological Survey, are found northwest of the outlet of Mooselucmaguntic lake.

The strata here have nearly an east and west strike and are vertical, but this is probably due to a great mass of intrusive granite between this and the river that joins the lakes on the south.

The lithological character of the rock is similar in every respect to the rocks found in the vicinity of Mount Washington, and it is probably a continuation northward of the rocks so extensively developed along the Androscoggin river in Gorham, N. H., and eastward. This is near the northern limit of these rocks in the area we have studied.

Mica schists with staurolite. South of Mooselucmaguntic lake in townships D and E, and extensively developed in the town of Bryon, there is a series of rocks consisting of fine-grained thick-bedded mica schists that carry staurolite. These schists, wherever observations were made, have a dip almost directly north, and the

inclination does not usually exceed 45°, especially northward. From the south they follow directly on the White Mountain gneisses.

Chloritic and whitish argillitic mica schists. North of the rocks last mentioned and east of the White Mountain gneiss, near the northern part of Mooselucmaguntic lake and extending east beyond the outlet of Rangely, there is a series of rocks consisting chiefly of chloritic and whitish argillitic schists. They are noticeable on account of their unconformability with the rocks east and south, and the abundance of quartz which they contain, and which lies in the line of the stratification. This rock forms ledges at Frye's Camp, at Houghton's Camp, and on the ridge immediately south of the Mountain View House at the outlet of Rangely lake.

Bald Mountain, an isolated peak between Rangely and Moosel ucmaguntic Lakes, though chiefly granite south of the ridge just mentioned, has upon its very summit a great mass of this schist which was caught in the granite.

Indian Rock at the mouth of Kennebago river and famed in the annals of fishermen, is a wonderfully contorted argillite, and may possibly belong to a different series of rocks. The hill immediately north of Cupsuptic lake is a light gray argillitic schist, the strata are nearly everywhere vertical and the strike is N. 40° E.

Northward along the Cupsuptic river there is no outcrop of rocks for several miles, but at the Falls of the Cupsuptic, a rock similar to the last is found. It differs from it in being of a darker color, is somewhat more silicious and weathers with a pitted surface near where it comes in contact with an intrusive granite. Having seen a similar change elsewhere in the same kind of rock, under the same circumstances, it is more than probable that the granite was in some measure the cause of the change.

Sandstone schist. Three miles north of Kennebago lake, on the Kennebago river, we find a sandstone schist, though it often resembles a mica schist; yet nearly everywhere there is no doubt as to the character of the rock, and in some localities the fragments of which it is composed are a quarter of an inch in diameter, and very distinct, especially upon the weathered surface of the rock. Elsewhere it has been greatly changed, and in some localities we find crystals of feldspar that have been produced since the sedimentation of the rock. This sandstone extends northward some eight miles along the Kennebago river. On the mountain ridge

north of Kennebago lake where the sandstone first appears, the strata are nearly vertical and the strike is N. 70° E., but along the river the strike is more northerly. South of this great area of rock we have red and light gray argillites, and on the north we have diorite with serpentine.

This sandstone schist is the rock on the boundary at the headwaters of the Cupsuptic river, and it extends at least three miles southward along that stream, and the same rock outcrops on the Magalloway at Little Boy's Falls north of Permachene lake, so that the area of this rock is exceedingly irregular in outline.

Northwest of Kennebago lake and extending south below the Falls on the Kennebago river, there is an area of light gray, dark purple and red argillites. The strata are vertical where observations have been taken, and there are sudden changes from one variety to the other. These argillites are probably the finer sediments derived from the great mass of material from which the sandstone schists were formed.

Diabase and diorite with serpentine. Diabase occupies an area on the Kennebago river; the most northern outcrop is about a mile from its mouth and it extends a mile and a half northward along the river and eastward towards Quimby pond. It is not altogether certain that this is a metamorphic rock, and if only the southern outcrop had been seen, and the rock had been studied only in the field, we could have reached no other conclusion but that it was intrusive, yet other outcrops strongly indicate that the rock is stratified.

At the head of one of the northwest branches of the Kennebago, which rises near the point where the boundary extends farthest southward, there is a fine-grained, greenish rock, which would probably be distinguished as melaphyre by the German Geologist. The area is limited here, but there are extensive outcrops on the boundary of New Hampshire, the summit of Mt. Camel being composed of a similar rock. The metamorphic diorite is one of the most interesting rocks found in this section of Maine. It outcrops on the Kennebago about twelve miles north of Kennebago lake. Very few ledges are seen; the boulders, however, are large and very numerous. But what is most important, it is undoubtedly the rock, the metamorphism of which has produced the serpentine which is also abundant here.

The boulders of serpentine are first found in great numbers

about ten miles north of Kennebago lake. They are enormous in size, sometimes thirty or forty feet in length, and with these there are boulders of diorite of nearly the same dimensions. But where the ledges appear the diorite evidently passes into serpentine.

Argillitic mica schist with staurolite. West of the gneiss, containing limestone in Phillips, we have a mica schist which westward in Madrid becomes quite argillaceous, and then again in the southwest corner of Madrid and in Sandy River Plantation, and west as far as Rangely lake, this rock has more the characteristic of a typical mica schist. The strata are everywhere vertical or nearly so, and often there are beautiful crystals of staurolite.

One of the finest outcrops with these crystals is at a school-house north of Sandy river, three and a half miles west of Madrid village. In the river below the dam at Madrid village there is fine-grained, thick-bedded mica schist, that contains concretionary nodules of granite from three inches to a foot in length and from two to eight inches in width. In the larger ones the proportional width is much less than in the smaller one. Five rods below the dam the fissile andalusite schist has essentially the same strike and dip as the compact mica schist above. Northwest of Madrid village there is a large area of ferruginous schists that probably belong to different series of rocks from those we are considering. In the west part of Sandy River Plantation, and in the east part of Rangely, we have mica schist with staurolite. This schist is extensively developed on Saddle-back stream, which flows near the Greenvale House. Following up this stream we find for nearly half a mile both the schist and the conglomerate, and there is such an intermingling of the two that unless there have been great changes in the rocks since they were uplifted to their present position they must belong to the same series. When the stream turns and comes more from the East, we have the conglomerate; and above, a deep gorge has been cut in the schist along the strike. On the hill southeast of the Greenvale House where the steep ascent begins, there is a mica schist with staurolite, and the dip is S. 20° E. 82°. There is a conglomerate included in this and unconformable with it. On the face of the cliff it is not more than 120 feet in width, but it becomes wider as we ascend the hill; it dips N. 30° W. 75° and stands on the upturned edges of the staurolite schist, so it is clear that we have two bands of conglomerate. Just south of the inlet of the lake the schist and conglomerate have

the same relations that they do on Saddle-back stream. This schist is more extensively developed in this section of Maine than any other rock, for, with some of the White Mountain gneisses and schists, it occupies the whole country to the northwest as far as Dead river in Flagstaff.

Rangely conglomerates. This conglomerate has given rise to much discussion on account of the flattening and distortion of some of the pebbles of which it is composed, but its stratigraphical relations have received very little attention. It is confined to a limited area extending N. 30° E. and S. 30° W., from the inlet of Rangely lake, and is not far from a mile in width, but becomes narrower northward, and in the middle of Dallas Plantation it is only a few rods in width. In the stream near the Greenvale House there seems to be on the weathered surfaces a marked difference between the staurolite schist and the conglomerate, but breaking the conglomerate, every portion of it except where there are actually pebbles, resembles in all respects the schist, and even the staurolite is not wanting. Going across the stratification we find places where there are an abundance of pebbles, and then they are wanting altogether or have been so changed that they are not apparent. There are fine outcrops of conglomerate three-quarters of a mile from Greenvale on the road to Rangely and at Moxy Ledge, near the inlet of the lake; some of the fragments at the former locality are a foot in diameter. The conglomerate on its northwest border, both north and south of the lake, passes gradually into a rock which, without a lens, cannot be distinguished from common gneiss. It seems more than probable that this conglomerate was formed on the shore of an old pre-Cambrian sea.

Palæozoic.

Wrinkled argillaceous schists with hard micaceous bands. West of the conglomerate there is a broad area of rocks consisting chiefly of wrinkled argillaceous schists and a few hard micaceous bands. It is found on the hills south of Rangely lake, and north of the lake it extends from where the conglomerate ends nearly to the outlet. In the east part of Rangely it is limited northward near Gull Pond by an intrusive diorite, but west it extends about three miles north of Quimby Pond. This band of rocks has one characteristic in common with some of the palæozoic rocks in New

Hampshire, the veins of quartz by which it is penetrated as well as those in the rocks immediately adjoining it have a decidedly fœtid odor. There is a band of the schist in the hill southeast of Greenvale, so it either extends around the Rangely conglomerate or there is here a repetition of the band to the west. The conglomerate mentioned as being found on this hill seems to be associated with this schist rather than with the staurolite schist.

Lower Helderberg and Oriskany. There is quite a large area in the vicinity of Kennebago lake that most probably belongs to the Lower Helderberg and Oriskany; from their fossils we are sure that some of the rocks belong to these groups. The area of Lower Helderberg and Oriskany, in the vicinity of Parlin Pond, has been known for many years, and its limits on the southwest have been pretty clearly defined. The area in Flagstaff was pointed out for the first time by me at the Portland meeting of this Association, and this now adds another to the many areas of these rocks already discovered.

Slates. There is a band of argillaceous rocks unlike, in their physical characteristics, any we have described, which outcrops on both sides of Kennebago lake. The most southern outcrop seen is on Spotted Mountain, south of John's Pond, the most northern on Kennebago East Mountain. The rock is generally thick-bedded, sometimes has the appearance of an argillaceous sandstone and is sometimes a little micaceous, but occasionally the finest and most purely argillaceous bands pass suddenly into a slate conglomerate. The argillaceous rock on the ridge between John's Pond and the south end of Kennebago lake breaks up into fragments more like shale than slate. The strike of this rock is N. 40° W.

Slate conglomerate. The transition of the slate into conglomerate is so sudden that we do not suspect its presence until we see the boulders or ledges where the change occurs. Boulders of slate conglomerate are abundant on the southern shores of Kennebago lake and outcrops in the vicinity of Flatiron Pond.

Calcareous sandstone with fossils. Several years ago Mr. H. P. Dill found boulders of fossiliferous rocks along the river in Phillips, hence it has been known that fossiliferous bands existed somewhere in this section. The rocks seen in the vicinity of Kennebago lake are not the same as the boulders of Phillips, though further exploration may show that they are found here, but it seems more prob-

able that the ledges whence the Phillips boulders are derived are in some other locality. The Phillips boulders are a pure sandstone with fossils of Lower Helderberg types, while here the rock is a calcareous sandstone with some fossils that are found with the Oriskany in the vicinity of Parlin Pond. The change, however, does not appear to be any greater than it is between Parlin Pond and Moose River. It has long been known that the line of demarcation between the Lower Helderberg and Oriskany in Maine, is not so well defined as it is in New York. At Kennebago lake the number of species is quite limited, and they can scarcely be distinguished except upon the weathered edges of the rocks where some of them are well brought out.

The fossiliferous rocks here are probably limited to the area north of Spotted Mountain between Flatiron Pond and the bridle path.

Cenozoic.

Glacial drift. The study of drift in a region entirely covered by forests is more difficult even than the study of the ledges. In the vicinity of Rangely lake, however, where there are farms, the absence of stratified drift generally is very noticeable. The most common boulders in the country about the east end of Rangely lake are diorite, and these are probably derived chiefly from the numerous dykes in the western part of the town of Rangely. There are very few boulders except diorite on the bridle path to Kennebago, until we get within three miles of the lake, when we have those of slate conglomerate, fossiliferous, calcareous sandstone, and a few granite boulders.

About ten miles north of Kennebago lake, particularly on the west side of the river, we find a remarkable collection of boulders; they consist of sandstone schist, serpentine and diorite, with a few granite boulders, but as we go northward the granite boulders increase, and soon they begin to predominate and the others disappear altogether. Some of these boulders are of enormous size, and are probably derived from ledges in their immediate vicinity. There is another great collection of boulders on the Cupsuptic river below the gorge already referred to, and these are derived from the granite ridges on either side of the stream, for after we pass the granite ridges these boulders disappear. Elsewhere no great collections of boulders were observed. The drift striæ on

Bald Mountain, between Mooselucmaguntic and Rangely lakes are S. 55° E. Near Rangely, on the south side, and near the inlet S. 35° E. and on the high land southeast of Dodge Pond S. 65° E., the striæ are in the direction of Saddle-back Mountain.

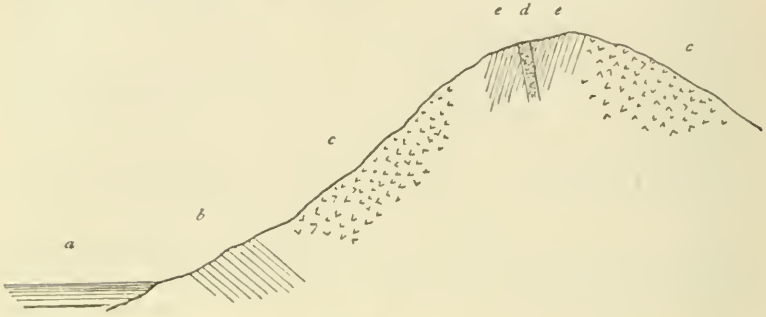
Modified drifts, kames, etc. A few gravel ridges in the west part of Dallas Plantation, were the only gravel deposits resembling kames that were seen in the vicinity of Rangely lake. On the lower part of the Kennebago river, there are some well marked kames, and their absence is also noted on the river until we get about ten miles north of Kennebago lake, where there are some well marked ridges, but these do not extend more than two miles. On the Cupsuptic river, there is an almost entire absence of kames, as in the other regions that were traversed, but on the lower part of the Cupsuptic for six or eight miles there are sand and gravel plains extending some distance from the river. These sand plains are characteristic also of the Magalloway, but as far as our observation goes they are wanting on the Kennebago.

ERUPTIVE ROCKS.

Granite. On the northwest branch of the Kennebago river near its source, there is a band of granite probably two miles wide. It is a typical variety, consisting of quartz, feldspar and mica in more nearly equal proportions than we often find them. There are, however, two kinds of feldspar which is not very common in the coarser varieties of the New England granites. On the Cupsuptic river in No. 4, R. 4, we find a similar kind of granite that extends north and south nearly through the entire range. Southwest in No. 5, R. 1 and 2, there are large areas of granite, but its greatest development we find on Observatory and Aziscohos mountains, and there is quite an extensive outcrop in No. 4, R 1, on the southwest side of a hill northwest of Upper Dam. The top of Bald Mountain between Rangely and Mooselucmaguntic lakes, except its very summit, is composed of this same coarse granite; the way in which the schist is caught shows better the intrusive character of the Conway granite than any other example we have seen.

The figure here inserted shows clearly this feature. To the left, on the border of the lake (*a*) we have the schist (*b*) with an easterly dip, and as we ascend the mountain the granite (*c*) sud denly appears and extends almost to the very summit which is

crowned with the same kind of schist (*e*) as that at the base; but in it is a well-defined band of granite (*d*) about six feet wide, cutting it so sharply, that the dip is essentially the same near the band as that of the mass on either side.



BALD MOUNTAIN.

Southeast of Mooselucmaguntic lake, in township D, on the head-waters of Swift river, there is a band of granite, but of a finer variety than those found northward.

Diorite. The most extensive outcrop of intrusive diorite, found in New England, has its southern limit near Gull pond, and outcrops are found for more than four miles northward. Southeast of Kennebago lake it forms a sharp mountain ridge which rises more than six hundred feet above the lake. The rock is generally a mica-diorite, and it often contains garnets. On the southern limit of this diorite there are fragments of schist, and it probably also penetrates the palæozoic strata in the vicinity of Kennebago lake. There are many dykes of diorite in Rangely immediately north of the lake, and the rock resembles the great outcrop northward except that there is more hornblende and fewer garnets.

Felsite. The summit of the diorite ridge, southeast of Kennebago lake, is chiefly a compact feldspar, and one variety contains a few garnets and a little mica; this forms great cliffs near the summit of the ridge.

In determining the stratigraphical relations of the rocks of this region, where the sequence was not apparent, I have correlated the strata with those determined by the Geological Survey of New Hampshire.

On the Annual Deposit of the Missouri River during the Post-pliocene. By J. E. Todd, of Tabor, Iowa.

[ABSTRACT.]

During the Alluvial epoch of the Champlain period the Missouri was an "unfinished river," probably like the present St. Lawrence, consisting of a chain of fresh-water lakes. One of these lakes, occupying thousands of square miles of Iowa and Nebraska, at first may have been over 300 feet deep, in limited areas near the present channels of the Platte and Missouri. Toward its shores it was very shallow. For an indefinite period it was gradually filling with the silt brought down by numerous rivers flowing into it. This *lacustral* deposit is of a yellowish, ashy color, and is composed of more than 80 per cent. of minute rounded grains of clear or yellow quartz, which rarely exceed .005 inch in diameter and average less than .001. It has been described as "perfectly homogeneous," and specimens from widely separated localities are usually undistinguishable.

A continued study, however, brings out many differences. Some portions have calcareous concretions, others ferruginous; some show a predominance of the yellow tinge, others the ashy; some contain abundance of land and fresh-water shells, while generally there is little or no trace of them. Very commonly the deposit is distinctly though very finely stratified. Some marks, very generally found, seem like the traces of roots, others of worms, and so far below the surface that they can scarcely be recent.[1]

But it is the purpose of the writer to call attention to certain marks that seem of greater interest and importance.

Several railroads traverse the formation in different directions, and the atmosphere acting upon the various exposures made by them has, by its delicate touch during the past ten years, brought out certain characters that had before escaped the geologist's eye and chemist's crucible. The localities where the most satisfactory

[1] These marks are very probably such as have been noticed by Baron Richthofen in the Loess of China, and from which he argues the sub-aërial origin of the deposits, *vid.* Am. Naturalist, Vol. XI, p. 711. Since reading the article just referred to, the writer has examined more carefully and found living rootlets of some herbaceous plants, probably grass, fifteen feet below the surface. How much farther they descend he has not yet determined.

observations have been made are in the cuts on the B. and M. R. R., east of Glenwood, Mills Co., Iowa, and within three miles of that place. In that distance the railroad descends over 225 feet, from the uplands to the flood-plain of the Missouri. It passes through ten cuts, two of them over thirty feet in depth, and the vertical sections of some overlapping. An excellent opportunity is therefore given for studying the strata and fossils of this Loess or Bluff deposit.

The attention of the writer was first attracted by quite deep furrows or benches traversing the sloping sides of the cut, in a horizontal direction. Another curious fact was discovered not long after. The cottonwoods and willows, which had sprung up in considerable numbers in the sides of the cuts, were distributed in several cases quite distinctly, in horizontal rows or strips, and what was more astonishing, such an arrangement could not be explained by the difference in slope of the surface at different levels, because the rows were quite as noticeable in cuts without distinct benches, as in those where they were most distinct. Moreover, in the latter the trees were quite as frequently on abrupt slopes as upon the gentle ones or bottoms of the benches.

After studying upon the problem for several months without finding any prospect of a solution, a visit was made to the locality, fortunately, on a hot drying day just after a soaking rain. One unknown quantity was seen at a glance, at one of the deepest cuts. Crossing the north side of the cut horizontally, were four or five wet zones, twelve to eighteen inches in width, showing with varying distinctness their darker color, contrasted with the light yellow of the intervening layers which had dried more quickly. Moreover, these wet zones corresponded closely with the strips of young trees.

A recollection of seeing, a few days before, how the cottonwood seeds, when swept like snow before the summer breeze, failed to remain on the dry road, but fairly "frosted" the mud by the road side, quickly led to the conclusion that the damp layers of the cut caused the rows of trees, both by catching the flying seed and supplying moisture for sprouting and nourishing it.

The unequal drying of the surface could not be explained by the inequalities of slope resulting from the benches, for the wet zones could be traced where there were no benches and across slopes of very different inclinations. Perhaps strangest of all,

the wet zones with the rows of trees were found to correspond, in the vertical distances between them, with the furrows or benches in the same cuts. This correspondence though very general, was not exact in every case. The wet zones were usually just above the loose layers producing the benches.

These three things, therefore, the rows of trees, the wet zones, and the benches,[2] were so many corroborating and mutually supplementary traces to guide to further discoveries, and perhaps to the causes back of all. By an examination of the various cuts mentioned, these additional facts were found.

In the lower part of the Bluff deposit, there is, in the locality under consideration, a succession of similar strata about every four feet. From a particular section the intervals, measured between the tops of the loose layers or bottoms of the wet zones, taken in order, were forty-two inches, forty-eight, fifty-five, fifty (?) and fifty-three.

In the middle Bluff deposit they were about three feet, and higher up in the formation, less. Within 100 feet of the top of the formation the intervals of twenty-four and twenty-seven inches were noted, and still higher thirty(?), thirty-six and twenty-four, in succession.

These are the facts observed. How can they be explained? They point to some causes, which acted similarly at nearly regular intervals. What can have produced that regularity? Nothing more plausible suggests itself than the revolution of the seasons. In fact no other influence suggests itself, and this, to one accustomed to think of geological forces as working with almost inconceivable slowness, is far from satisfactory, at least at first.

The next step for the writer was to study the present deposits of the Missouri, seeking answers for such questions as the following:—

Is there any perceptible difference between the deposits of high water and low-water? How much solid matter does the water, flowing at its present velocity, contain in each stage? In restricted areas overflowed by the river, what depth of deposit is formed in a given time?

He found from Prof. R. Emory's analyses, recorded in the

[2] Later observations have revealed another clew, viz., zones of moss, which, nourished by the wet zones, mark them, in some cases quite distinctly, after the extra moisture has disappeared, as in mid-summer.

"Iowa Geological Report," that high water of the Missouri, contains $\frac{1}{176}$ of its weight of solid matter undissolved, of which over 84 per cent. is silica, and over 12 per cent. iron, alumina, and calcium carbonate; that low-water contains $\frac{1}{2170}$ of solid matter, of which only 75 per cent. is silica, while there is over 22 per cent. of the other substances named.

Assuming that the silica is in the form of the minute grains before mentioned, while the other ingredients form the finer cementing and coloring elements, we should expect a deposit during a freshet to be more *sandy*, and that from quietly flowing or still water, more *clayey*. Such expectations were fully realized by examination. From a slough, freely connecting with the river at high water, afterward becoming a quiet pond and finally drying up each season, the following section was obtained, from the surface down:

$4\frac{1}{2}$ inches, impalpable clay.
$4\frac{1}{2}$ " fine sand.
$4\frac{1}{2}$ " of clay.
6 " sand.
then clay again.

On the surface of a prairie, where the river, this last spring, escaped from a sharp bend, when at its highest stage, and flowed for two weeks with a depth of less than four feet, and where no water stood after the river subsided, a deposit of fine sand only was found, which was from eight to eighteen inches deep.

These facts suggest and impress the thought that the looser layers, marked in the railroad cuts by benches, were caused by the annual freshets of the Post-pleiocene Missouri; while the moist or clayey layers above them record the more quiet season following.

The variations of the ancient deposits are more marked in the localities mentioned, because they are so near the old, as well as the present, bed of the Missouri. The same fact will also assist in explaining the thickness of the same deposits.

In addition to the facts already given concerning the thickness of recent deposits, the writer would say that trustworthy witnesses

informed him that they could point to places where the Missouri has filled portions of its bed from twelve to eighteen feet in depth in a single season. Much of this, however, is a result of its pushing rather than its depositing action. Yet, if the sediment of water, passing a certain point only partially checked and only four feet deep, fills up about ten inches in two weeks, what possibilities are conceivable, in the case of a large and rapid river wholly checked, and all its sediment settling to the bottom!

To assist in such a conception and at the same time give something more substantial than mere fancy, let us take the data furnished by the "U. S. Report on the Physics and Hydraulics of the Mississippi," and modify them to suit our ideas of the Champlain period, as derived from other sources.

If the rainfall was then as great in the Missouri basin as it is now in that of the Ohio; if owing to the lack of vegetation three-fourths of the rainfall should find its way into the river channels; if the melting glaciers furnished as much water as the whole rainfall; if the proportion of silt transported averaged about the amount observed at high water at Council Bluffs, as given above; the silt poured into this lake would be enough to cover an area equal to Lake Ontario, to a uniform depth of 3.62 feet, annually. This area would perhaps equal in extent the deeper portions of the ancient lake, those lying beneath the principal currents. The deposition would doubtless be very uneven, deeper in limited localities and very shallow away from the main currents.

Therefore, the conclusion seems not incredible, that *in some central portions of this ancient Lake Missouri, the annual deposit may have been at first as much as four feet in depth; that later it diminished to less than two feet, and probably toward the last was much less and more irregular.*

On the Classification of the Extinct Fishes of the Lower Types. By Edward D. Cope, of Philadelphia, Penn.

In the Transactions of the American Philosophical Society, published in 1871, and more fully in the Proceedings of the American Association for the Advancement of Science, at the meeting of 1871 (published early in 1872), I showed that the supposed order of Ganoids, as defined by Müller, is not a homogeneous or natural association of types. I pointed out that the recent genera must be distributed between two divisions of fishes of high rank, viz.: the *Crossopterygia*, and the *Actinopteri*. The last-named division was believed to include the fishes previously known as *Chondrostei* and *Teleostei*. Some of the so-called Ganoids of Müller and Agassiz were referred to different subdivisions of the *Actinopteri*. In a paper recently published in the Proceedings[1] of the American Philosophical Society, a better expression of natural affinities was thought to be obtained, by regarding the *Crossopterygia*, the *Chondrostei*, and the *Actinopteri*, as forming a single sub-class of the class Pisces, under the name of *Hyopomata*, the other sub-classes being the *Dipnoi*, the *Selachia*, and the *Holocephali*.

The following definitions of the four sub-classes were there given.

I. Suspensorium continuous with the cartilaginous cranium, with no hyomandibular nor rudimental opercular bone; no maxillary arch; pelvic bones present; axial series of fore limb shortened, the derivative radii sessile on the basal pieces; axial series of hinder limb prolonged in male . . . *Holocephali.*

II. Suspensorium articulated with the cranium; no maxillary arch; no opercular nor pelvic bones; bones of limb as in the last . . . . . *Selachii.*

III. Suspensorium rudimental, articulated with cranium, supporting one or more opercular bones; cranium with superior membrane bones; no maxillary arch; a median pelvic element; the limbs supported by segmented unmodified axes. . . . . *Dipnoi.*

IV. Hyomandibular and palatoquadrate bones articulating with cranium, supporting opercular bones; a maxillary arch; no pelvic element; axes of the limbs shortened, the derivative radii sessile on the basal pieces. . . . . *Hyopomata.*

The primary divisions of the *Hyopomata* are indicated by the

[1] May, 1877.

structure of the fins, of which there are three principal modifications as follows:

A. Derivative radii present in both limbs; in the anterior supported by an axial segment with one or more basal or derivative radii, forming a peduncle; in the hind limbs the derivative radii sessile on axial segment only . . . . . *Crossopterygia.*

B. Derivative radii few in the fore limb, sessile on scapula; present in hind limb, and sessile on axial segment . . *Chondrostei.*

C. Derivative radii few in the fore limb, sessile on the scapula; wanting or very few and rudimental on the hind limb so that the dermal radii rest on the axial element. . . *Actinopteri.*

The classification of the *Actinopteri* then continues as in the memoirs above quoted.

I had already referred *Phaneropleuron*[2] to the *Dipnoi*, when Dr. Günther's and Prof. Huxley's researches into the structure of *Ceratodus forsteri* led them to place this genus also in the same sub-class. Günther also refers the fossil genera *Dipterus*, *Chirodus* and *Conchodus* to the *Dipnoi*, and with these must go *Ctenodus* and its immediate allies. The *Polypteridæ* and *Cœlacanthidæ*, which were arranged by Huxley, with the preceding forms in his sub-order *Crossopterygia*,[3] are clearly *Hyopomata*, having well developed hyomandibular and maxillary bones, as well as characters of the pectoral fins equally wanting to the *Dipnoi*. It is thus evident that the division *Crossopterygia*, as left by Huxley, cannot be maintained, but that it must rest entirely on the definitions given by me in the papers above quoted, where the two families mentioned were the only ones referred to it. It is possible that a strict adhesion to the law of priority will require that the name *Ganoidei* should be retained for this division.

The tribe *Actinopteri* as left in my latest paper above quoted (May, 1877), has slightly different boundaries from those originally prescribed for it, since the *Chondrostei* are now excluded from it. As then and now understood, it is nearly identical with the *Teleostei* of Müller, a name which I should adopt for it, were it not that some of his *Ganoidei* and numerous extinct forms with unossified vertebral column belong to it. For such fishes the name of Müller is too glaringly inapplicable to be employed.

[2] Transactions American Philosophical Society, XIV, 1871, p. 450.
[3] Memoirs of the Geological Survey, Great Britain, Decade X.

After excluding the extinct genera of *Hyopomata* which are clearly *Crossopterygia* and *Chondrostei*, there remains a numerous assemblage, whose relationships to existing types of fishes have never yet been ascertained. I refer especially to the families of the *Lepidoides*, *Sauroides* and *Pycnodontes*, of the Poissons Fossiles of Agassiz, and other forms subsequently described; among others, the *Dorypterus* of Germar. The only bond which retained these forms in connection with the fossil Crossopterygian fishes, the rhombic and enameled scales, may be safely disregarded in view of the important characters of the skeleton which declare their affinities to be diverse; the more as some of the latter (*Cœlacanthidæ*) have rounded scales, and *Leptolepis* and other genera, referred by Agassiz to the Sauroides, have cycloid scales. The heterocercal character of the tail of some of them is of but little greater weight. I have already shown that fishes presenting this character (*Lepidosteus*, *Amia*) do not differ in other respects from other *Actinopteri*, while the still lower isocercal condition is often seen in the latter. Further, the extinct genera do not agree among themselves in this respect, some being heterocercal, and some isocercal.

The question remains as to the proper location of the families just named, in the tribe *Actinopteri*. It has been impossible to discover all of the characters necessary to the fullest elucidation of this question, but the greater number of them have been satisfactorily ascertained. The following results are therefore approximations to the truth which I believe that future researches into the osteology will confirm. At the least they are much nearer to an expression of nature than any yet attained.

As regards the general affinities represented by the terms *Physostomi* and *Physoclysti*, there is no doubt that the *Lepidoides* and *Sauroides* exhibit the former. This is seen in the uninterrupted conjunction of the parietal bones (where it has been possible to observe the parts), and in the abdominal position of the ventral fins, and extent of the maxillary bone; as well as in the less important features of the absence of all ctenoid characters of scales and preoperculum, lack of spinous rays, etc. The *Pycnodontidæ* present in general similar characters, and add nothing which should separate them widely from the Lepidoid genera of Agassiz, especially the family of the *Dapediidæ*. Like these, however, they approach nearer to the *Physoclysti* in the anterior continuation of

the interneural spines as far as the skull. This character is found also in some *Physostomous* fishes, *i. e.*, the greater number of *Characinidæ*, the *Elopidæ*, *Umbridæ* and some *Nematognathi*.

The *Dorypteridæ* present a number of peculiar features, approaching still more closely the *Physoclysti* in their thoracic ventral fins. We may now consider the relations of the Lepidoides and Sauroides to the known physostomous orders.

The scapular arch, being suspended to the cranium, renders comparison with some recent orders with a free scapular arch unnecessary. The simplicity of the anterior vertebræ leaves out of account the *Nematognathi* and *Plectospondyli*. The only orders with which we can compare them are those represented by their old companions in the Poissons Fossiles, the *Ginglymodi*, the *Halecomorphi* and the *Isospondyli*.

Although the *Sauroides* included the genus *Lepidosteus* in Agassiz's system, I cannot find that any of the fishes of the two families under consideration possess the peculiar vertebræ of that genus, which in part characterize the order *Ginglymodi*. Neither have any of them the segmented maxillary bone. The real alternative is between the last two of the above named orders. Now the principal skeletal character which distinguishes these two is found in the pectoral fin. In the *Halecomorphi* there are numerous basilar radii attached to a cartilaginous mesopterygium; in the *Isospodyli* there are but three or four such bones sessile on the scapular arch. After examining a number of specimens of species of both the Agassizian families named, I have been unable to discover any basilar bones whatever, and have suspected that they were, in the complete skeleton, of cartilaginous character. Professor Agassiz figures this region in his restoration of the "Lepidoid" genus *Platysomus*, and of the "Sauroid" genera *Macrosemius* and *Caturus*. In these he represents the small number of basilar bones characteristic of the *Isospondyli*, and placed in the close relation to the scapular arch which is seen in the same order. A consultation of the numerous figures given by Agassiz, Thiolliere, and others, has failed to discover a single instance exhibiting the peculiar basilar pectoral bones of *Amia*. This could scarcely be so uniformly the case did such bones exist, so that with Prof. Agassiz' restoration coinciding, I can only for the present refer these fishes to the *Isospondyli*.

Their other special characters are so numerous, that they must

be taken account of in deciding on their ordinal relations. If we, for the present, distinguish the two families as did Agassiz, we include in the Lepidoides the genera with teeth *en brosse* or in a single row, and sub-equal and obtuse; and in the Sauroides the genera with teeth of unequal sizes, some being large and raptorial, the others minute. Of the Lepidoid genera, Agassiz states that the vertebræ are osseous in *Lepidotus*, and says the skeleton of *Amblypterus* is osseous, without particularizing the vertebræ. The posterior vertebræ of *Pulæoniscus* he states to be ossified, while in *Platysomus*, *Tetragonolepis* and *Dapedius*, the centra are not certainly osseous. In all of these genera the neural and hæmal arches are distinctly articulated with the centra. *Platysomus*, *Dapedius* and *Tetragonolepis*, present the important character of a series of basilar interneural and interhæmal bones, the interneurals commencing in *Platysomus* at the head. This character separates these species widely from the other genera of the "*Lepidoides*."

As regards the "*Sauroides*," the vertebral centra are always represented as ossified, and the neural and hæmal arches articulated, with the possible exception of *Thrissops*[4] where the arches are represented as continuous; the same point is not certainly determined in *Eugnathus*. None of the genera which I have seen have the basilar interneural and interhæmal spines found in the *Dapediidæ*, above mentioned, nor are they figured or described by authors.

In these characters of the two groups, there is nothing allying genera to the *Halecomorphi* rather than to the *Isospondyli*. The absence of the basilar interhæmals from all excepting the *Dapediidæ* is additional evidence of Isospondylous affinities. The ganoid scales of most of the genera do not separate them from the typical forms of this order more widely than the *Arapæma*, nor the vertebrated caudal fin more widely than the existing *Notopterus*. The number of vertebræ included in the axis of the caudal fin in the extinct genera is shown by Agassiz to be very variable. In *Megalurus*, this region resembles that of *Amia;* in *Leptolepis* and *Caturus*, the vertebræ are not more numerous than in the *Saurodontidæ*, while in *Thrissops* the fin is homocercal, in the Agassizian sense.

[4] Description of Poiss. Foss. prov. d. l. Gisem. Jurass. d. le Bugey; premiere livr. Thiolliere et Gervais.

As already remarked, the *Pycnodontidæ* present some points of resemblance to the *Dapediidæ*. All the points necessary to a complete elucidation of their structure have not yet been observed, so that my conclusions are necessarily imperfect. A point of resemblance to the *Plectognathi* is seen in the cartilaginous space between the interneural and interhæmal spines and their respective fins; a space occupied in the *Dapediidæ* and *Dorypteridæ*, by the basilar interneurals and interhæmals. This character is, however, not universal in the *Pycnodontidæ*. Prof. Agassiz speaks (Poissons Fossiles) of a maxillary bone, which bears a few teeth, in this family. This character will distinguish it at once from the *Plectognathi* and all other physoclystous orders. The abdominal position of the ventral fins and unmodified anterior vertebræ indicate that these fishes may for the present be placed with the preceding, in the *Isospondyli*. There they are well distinguished by the peculiar inverted chevron-like bones which protect the dorsal and lateral regions in front of the dorsal fin. Prof. Agassiz describes the vertebræ of *Pycnodus* as osseous; M. Thiolliere figures some species as without osseous centra, a condition I have observed in some specimens.

The characters of the *Dorypteridæ* are, according to the very full description of Messrs. Hancock and Howse,[5] more strongly peculiar. Although these fishes may be referred to the *Physoclysti*, on account of the thoracic position of their ventral fins, they present features which will not permit a reference to any known order. It has been shown that they possess the basilar interneural bones, which, as I have pointed out,[6] only exist in the *Physoclysti* in small development in the *Batrachidæ;* and occur in various degrees of development in some *Physostomi*, being especially elongate in the anal fin of Amia. It is even possible that another element enters into the series connecting the neural spines with the dorsal fin-rays. The pectoral fin possesses fourteen or fifteen basilar radial bones; a character which, like the last, is not found in the *Plectognathi;* these fishes having but three or four such elements. These two points indicate a lower position than that of the latter order, and a relation to it similar to that which *Amia* bears to the *Isospondyli*. It goes to show that even among some of the earlier fishes, physoclystous characters were foreshadowed. I therefore establish a

[5] Quarterly Journ. Geolog. Society, London, 1870, p. 623.
[6] Transac. Amer. Philos. Soc. 1871, XIV, p. 451.

new order for its reception to take its place at the base of the line of Physoclysti.

As a résumé of the preceding inquiry, the following table of the families treated of, with their definitions, is now given:

Order ISOSPONDYLI.

Physostomous fishes with distinct parietal bones; unmodified anterior vertebræ, and three or four basilar bones of the pectoral fin. Symplectic and præcoracoid bones present so far as known.

Fam. SAUROPSIDÆ (*Sauroides* Agass. partim.)

Teeth of different sizes, the large raptorial ones mingled with small ones; vertebral column osseous; no basilar interneurals or interhæmals.

1. Caudal fin with many vertebræ; scales rhomboid;— *Pygopterus Eugnathus.*
2. Caudal fin with few vertebræ; scales rhomboid; — *Pachycormus,*[7] *Sauropsis, Macrosemius, Belonostomus, Aspidorhynchus.*
3. Caudal fin with numerous vertebræ; scales rounded; *Megalurus, Callopterus,*[8] *Attakeopsis.*[8]
4. Caudal fin with few vertebræ (in some instances apparently none); scales rounded;— *Caturus, Leptolepis, Anædopogon*[9], *Thrissops.*

Fam. LEPIDOTIDÆ (*Lepidoides* Agass. partim.)

Teeth simple, often obtuse, in one or many rows, without elongate ones intermixed; no basilar interneurals or interhæmals; vertebræ with the centra incompletely ossified;[10] (scales rhomboid; caudal fin vertebrated.) *Amblypterus, Palæoniscus, Eurynotus, Semionotus, Lepidotus, Pholidophorus, Microps, Notagogus, Ophiopsis, Cosmolepis, Pleuropholis.*

Fam. DAPEDIIDÆ mihi.

Teeth uniform, obtuse; vertebræ with incompletely ossified centra;[10] the interneural spines commencing at the head; a complete series of basilar interneural and interhæmal spines;[11] *Platysomus, Dapedius, Tetragonolepis.*

Fam. PYCNODONTIDÆ.

Teeth obtuse, molar, covering the vomer and palatine bones; no basilar interneural and interhæmal bones; chevron-shaped bones protecting the dorsal region, their branches extending on the sides; abdomen protected by similar bones, which form plates on the median line; interneurals continued far forwards.— *Microdon, Pycnodus, Gyrodus, Mesodon.*

[7] Vide *P. heterurus* and *P. macropterus* Ag.
[8] Thiollière et Gervais Poissons Foss. de Bugey.
[9] Cope, Proceedings American Philosophical Society, 1871, p. 53.
[10] These statements are derived from Agassiz, Poissons Fossiles.
[11] Agassiz. Poiss. Fossiles, II. Pl. D. fig. 2.

Order Docopteri mihi.

Scapular arch suspended to the cranium; pectoral fin with numerous (not more than fifteen known) basal radii; ventral fins thoracic. Dorsal and anal fins with basilar interneurals.

Fam. Dorypteridæ.

Vertebral column osseous; caudal fin not or very shortly vertebrated. Interneural spines corresponding with the basilars on the abdominal, but not on the caudal parts of the vertebral column. Ribs complex, united with abdominal dermal bones which form a series of median plates.

None of the Isospondylous families above described possess the dental characters of the *Saurodontidæ*, i. e. the long fangs set in deep alveoli. I now devote some attention to a family presenting this character, which is also the type of a peculiar order which I have called the

Actinochiri. [12]

Six single and one paired basilar bones supporting the pectoral fin, all articulating with the scapula; anterior vertebræ unmodified. Mandible complex, the coronoid, angular and articular bones all distinct. Maxillary and premaxillary bones distinct.

The only family of this order yet known is that of the *Pelecopteridæ*, which is thus defined.

Pelecopteridæ: Premaxillary bone forming but a small part of the arcade of the mouth, and articulating with its superior border in a groove of the ethmoid bone. An interior element (splenial?) of the mandible extending to the symphysis, and supporting teeth.

There are two genera of this family, *Pelecopterus* and *Erisichthe*. The ethmoid bone is produced into an elongate beak, which supports at its base on the inferior side, two huge teeth, which issue from deep alveoli. The teeth of the premaxillary and anterior portions of the dentary and splenial bones are larger than the remaining teeth. Those of the principal series are compressed and furnished with sharp edges, while there are supplementary rows of small conical teeth on the splenial, dentary and parasphenoid. The occipital articulation is deeply excavated. The pectoral fin consists of a single spine, composed of all the rays solidly coherent, whose anterior border is acute.

[12] Report of U. S. Geolog. Surv., Terr., F. V. Hayden, II, p. 244 A.

Four species of *Erisichthe* have been described; *E. nitida* Cope (Rept. U. S. Geol. Surv., Tenn., II, p. 217); *E. dimidiata* Cope (*E. nitida*, Bull., U. S. Geolog. Surv., Tenn., 1877, III, 822); *E. penetrans* and *E. ziphioides* Cope.

Figures of the mandible of this genus are given by Dixon in his Geology of Sussex, who referred the species to *Saurocephalus*. Sir Philip Egerton discovered, during the publication of that work that the ziphioid muzzle found in the same formation belongs to the same fishes. After my discrimination of the genus *Erisichthe*, in the United States, Prof. Mudge discovered the association of the snout and jaws. I now correlate for the first time the cranium with the pectoral arch and fins heretofore known as *Pelecopterus*.[13]

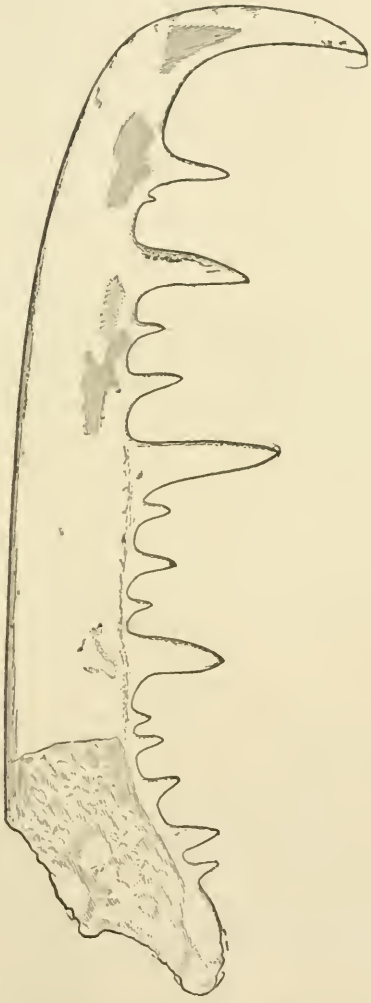
New Specimen from the Water-lime Group at Buffalo, N. Y. By A. R. Grote and W. H. Pitt, of Buffalo, N. Y.

In the "Palæontology of New York" Prof. Hall describes a species of the genus *Pterygotus* from a specimen of the "free ramus of the chelate appendage;" this specimen was found in the water-lime group near Buffalo. In September, 1875, we described a still larger species under the name of *Pterygotus cummingsi* from the same locality. The species was founded on a specimen showing the basal joint of one of the swimming feet (maxilliped or ectognath). In the specimen the toothed mandibular margin is well shown with a portion of the adjoining lateral margins. The near resemblance of this specimen with the corresponding parts in *P. angelicus* of Agassiz from the Old Red sandstone shows that the maxilliped does not give good distinctional characters.

We have now discovered the ramus of *Pterygotus cummingsi* from

[13] This was first published in the "American Naturalist" for February, 1878.

the same beds. The drawing of this portion of the body here annexed allows of a comparison with *Pterygotus anglicus* Ag., and *P. cobbi* Hall. It is seen that, in size, it is proportionate to the



maxilliped previously discovered. The length of the specimen is five and one-sixteenth inches ($5\frac{1}{16}$); the corresponding piece in *Pterygotus cobbi* measures three and three-sixteenths ($3\frac{3}{16}$). In

Pterygotus anglicus the same piece measures three and five-eighths ($3\frac{5}{8}$) inches. It will be seen that the present specimens show that the American species *cummingsi* is perhaps the largest known of the genus. In the restored figure of *Pterygotus bilobus* given by Profs. Huxley and Salter the same joint measures five-eighths ($\frac{5}{8}$) inch. The whole length of the animal was six and three-quarters inches ($6\frac{3}{4}$). Proportionately, and judging also from what we know of the ectognath, *P. cummingsi* attained a length of nearly five feet. *P. cobbi* was about three feet long, on the same approximate estimate. A comparison shows that in the new specimens the apex of the joint is pointed; in *P. cobbi* and *P. anglicus* it is obtuse. The arrangement of the teeth is different in *P. cummingsi*, while both this species and *P. cobbi* differ from *P. anglicus* in the greater narrowness of the ramus. An examination of the test shows that the teeth possessed a longitudinally striated structure in *P. cummingsi*. With regard to the fragment figured by Prof. Hall as probably belonging to *P. cobbi* (Pl. 84, fig. 8) we have elsewhere suggested from the character of the surface markings that it may belong to *Eusarcus*.

AGAMIC REPRODUCTION AMONG THE CYNIPIDÆ. By H. F. BASSETT, of Waterbury, Conn.

THE theory of perpetual agamic reproduction of certain species of Hymenopterous gall-insects which was forced upon the early observers of the Cynipidæ, and which was so greatly strengthened by the seemingly conclusive results of the experiments of the German entomologist, Hartig, thirty-five years ago, is still accepted as true by many entomologists.

Hartig's experiments consisted in rearing from certain species of oak galls vast numbers of gall flies, all of which were females; and as he continued these experiments for several years and always with the same results, the inference that no males existed was natural and apparently well supported.

The fact of agamic reproduction is established beyond doubt; but that it is not perpetual in any given species of the Cynipidæ becomes nearly certain in view of lately discovered facts.

In June, 1864, I found that the females of the very common two-gendered *Cynips q. operator* O. S. proceeded immediately after impregnation to lay their eggs in the acorn cups of the shrub oaks on which their woolly galls were found. A letter recording this discovery and describing the ovipositing process was published in the Proc. Ent. Soc. Phila., Vol. 3, p. 197.

I found in the autumn of 1864 that the acorns stung were either blasted or very imperfect, and that there were between the imperfect acorn and its cup, one or more pip-like galls each containing a true cynipideous larva. I endeavored to rear gall flies from these galls but failed, and after keeping them in the breeding boxes for more than a year threw them away.

A few years later I found very early in the spring, female gall flies ovipositing in the undeveloped buds of the shrub oak. These flies were larger than the females of *C. q. operator*, and, except in size, agreed closely with this species. They had all those structural peculiarities which render this the most distinct species we have. The oaks, where these insects were found, produced fine woolly galls that year, but I found on them no other kinds.

The same season Prof. C. V. Riley reared female gall flies from some of the acorn-cup galls which he and I had collected more than eighteen months before. These flies agreed in all respects — size, form, color, and time of appearance—with those I had taken in the act of ovipositing in the oak buds.

The history of this species briefly told is as follows:—

Two entirely dissimilar forms of gall — one affecting the buds of the oak which develop into woolly masses filled with larval cells, from which insects of both sexes are produced in great numbers about three months after the eggs are deposited, the other pip-like galls formed in the acorn cups of the same species of oak, which, so far as yet known, produce only female insects after the long period of twenty-one months from the laying of the eggs.

Another species (probably *C. q. batata* Bassett, though found on another species of oak), which I have carefully observed every year for the last twelve or fifteen years, produces *each year two generations* — one of which is from galls affecting the midvein of the leaves of *Q. bicolor*, and which consists of male and female insects;

and the other from tuber-like swellings of the ends of the twigs of the same oak, and which consists entirely of females. In this case as in that of *C. q. operator*, the galls are totally unlike, but the females of the two generations are absolutely undistinguishable.

I have reared many thousands of both generations. The insects from the leaf galls appear the last of June, and are about three months in coming to maturity; the others are nearly mature at the beginning of winter, but remain in the galls till the following spring.

Early this present year a German entomologist, Dr. Adler of Schleswig, published a very interesting paper upon the Cynipidæ. By a series of very carefully conducted experiments he has proved that at least seven of the *one-gendered* species of European gall flies are represented in the next generation by both sexes.

Dr. Adler's observations, as far as they relate to this subject, are briefly stated as follows:

All the species of *Neuroterus* are one-gendered. Gall flies, reared from *N. fumipennis* Hrtg., produced in the next generation *Spathegaster albipes* Schk., ♂ and ♀. *N. lenticularis* Ol. produced *Spathegaster baccarum* L., ♂ and ♀. *N. numismatis* Ol., *Spathegaster vesicatrix* Schlectendal, ♂ and ♀. *N. læviusculus* Schk. is represented in the next generation by *Spathegaster tricolor* Hrtg. He finds that *Dryophanta scutellaris* Ol.= folii Hartg., known only in the female sex, produces in the next generation *Trigonaspis crustatis* Hrtg., which is of both sexes.

Aphilothrix radicis Fbr., a one-gendered species, occurs in the next generation in both sexes, and is known as *Andricus noduli* Hrtg., and *Aphilothrix sieboldi* Hrtg., also one-gendered, is followed by *Andricus testaceipes* Hrtg., a two-gendered species.

The first named five species, viz., *Neuroterus fumipennis*, *N. lenticularis*, *N. numismatis*, *N. lævisculus*, and *Dryophanta scutellaris* produce, each, two generations in a year, one of which requires three and the other nine months for the complete development of the individual — the one composed of males and females, the other entirely of females.

The two species of *Aphilothrix*, however, like our American *C. q. operator*, require, in one generation three months, and in the other twenty-one months for their full development.

All these European one-gendered species differ in a marked degree from the females of the two-gendered broods. This dissimi-

larity is most apparent in their size, and in the structure of the ovipositor. That the differences are really considerable will appear when we state that the fourteen so-called species, which Dr. Adler has reduced to seven, were assigned to six distinct genera.

That the eighteen forms above named really constitute but nine species, will hardly be questioned—certainly not by those who read Dr. Adler's paper and notice the extreme carefulness with which he conducted his long series of experiments.

His observations also bring to light another phase of cynipideous life. He has reared, from unimpregnated females of *Rhodites rosæ* L., three consecutive generations of gall flies, all of the same kind and all from the Bedeguar galls which occur both in Europe and America. Both sexes of this species are met with, but the males are so exceedingly rare that Dr. Adler found only six or seven among as many hundred females.

Lepidopterists find that this mode of propagation exists in that order, but to what extent I do not know. I am under the impression that in all such cases the reproductive power grows weaker with each successive generation, and finally fails. I believe that experiments upon certain Lepidoptera have proved this, but I may be mistaken.

Dr. Adler is engaged in studying several other species, and promises to publish the results at an early day.

Dr. Mayr, of Vienna, is also at work upon the same subject, and I have given considerable attention to several of our species that evidently belong to the dimorphic class; but my observations are as yet too incomplete for publication.

In justice to Dr. Adler I will here state that, notwithstanding his very remarkable discoveries, he still believes that perpetual agamic reproduction exists. Possibly his unpublished observations sustain this view, but the evidence thus far is strongly against it.

We have several species of gall flies that are not dimorphic, but all those that are found only in the female sex are no doubt the progenitors of a generation consisting of both sexes. But it remains to be discovered whether these female broods alternate with broods male and female, and whether the periods of *three* and *nine*, and *three* and *twenty-one* months cover the cycle of change, as in the species thus far observed.

It is a fact which I do not remember to have seen noticed, that

the oak galls which produce insects of both sexes are those which mature in the spring and early summer, while the late summer and autumnal kinds as constantly produce only females. This is true of all the American and European species known to me. I cannot think of any exceptions to the rule.

By these discoveries the present nomenclature of the Cynipidæ becomes a good deal mixed, and I see no easy way to bring order out of the confusion. That which needs first to be done is to trace the relationship which exists between each one-gendered and its two-gendered form, a difficult but interesting work.

ON THE RESPIRATION OF AMIA. By BURT G. WILDER, of Ithaca, N. Y.

IN a brief communication [11][1] to this Association two years ago, there were described experiments made upon *Amia*[2] at Peoria, Illinois, upon the 10th of July, 1875.

These experiments showed that *Amia* occasionally exhales bubbles of air, and strongly indicated that each exhalation is followed by an inhalation.

These acts of apparently aerial respiration were observed to occur more frequently when the water was foul, or had not been changed.

During the present summer (1877) examples of *Amia* have been

[1] The bracketed numbers refer to a list of works and papers at the end of this paper. The first number designates the work; the last the page: the middle one, in Roman, the volume.

[2] *Amia* is a fresh-water fish of the United States. It is abundant in the Mississippi and its tributaries, and in the great lakes. It is not found in New England or eastern New York, or west of the Rocky mountains. It attains a length of two feet and is called by fishermen "mud-fish," "dog-fish," and "lake-lawyer." Under the jaw is a movable plate which does not exist in any other American fresh-water fish. On each side of the fleshy isthmus, connecting the tip of the lower jaw with the hyoid arch, are two serrated appendages which are nearly if not quite peculiar to this fish; [12].

Near the upper border of the base of the tail is a round black spot which is usually absent with the largest females. Several species of *Amia* have been described, but they are probably only varieties of *A. calva* described by Linnæus (1, I, 500). *Amia* is usually regarded as a Ganoid.

obtained alive and apparently uninjured, from the northern end of Cayuga Lake in central New York. An opportunity has thus been afforded for more systematic and extended observations and experiments upon this fish. Some of the results are herewith presented.

As the aerial respiration is undoubtedly accomplished by means of the air-bladder, the structure and relations of this organ must first be described.

The air-bladder of *Amia* is a median sack extending the whole length of the abdomen. The posterior extremity is rounded. Anteriorly it terminates in two conical projections or horns, between which is the longitudinal glottis by which it communicates with the dorsal side of the alimentary canal.

The cavity of the air-bladder is so much subdivided that Cuvier, [3] and others, compared it with the lung of a reptile. It is in fact more lung-like than the lungs of salamanders and frogs. Moreover, as was also remarked by Cuvier and Valenciennes [2, XIX, 409], this cellular network is traversed by fine ramifications of blood-vessels. Under the microscope, the capillary plexus presents a beautiful appearance.

The disposition of the vascular trunks has been figured, and briefly described by Franque [5, 8, and fig. 4]. On each side are a large artery and vein. The artery according to Franque [5], arises from the last (fourth) branchial vein or epibranchial artery. "The veins empty into the venous trunks of the body."

In five fresh examples injected[3] and carefully dissected, the arrangement is as follows. The first and second epibranchials are continued directly into the aorta. The third divides into two nearly equal portions. One part opens into the aorta on the left side, on the right into the commencement of the cæliac artery. The other part, which is the more direct combination of the trunk, passes backward, and is joined by the entire epibranchial of the fourth gill. The trunk so formed is the artery of the air-bladder. Its size equals that of the aorta after the giving off of the cæliac artery, and also that of the cæliac artery itself.

So far, therefore, as may be inferred from the relative diameters of the vessels, the air-bladder may receive, through its two arte-

[3] These injections were made by my laboratory assistant, Instructor S. H. Gage, whom I have to thank also for very accurate observations of *Amia* during several hours of my absence.

ries, a volume of blood equal to that which the aorta and cæliac artery carry to the trunk and abdominal viscera.

The efferent vessels, or veins, of the air-bladder open into the sinuses of Cuvier nearer the heart than do the great cardinal veins of the trunk.[4]

The air bladder lies between the spine and the alimentary canal; and on each side is a sheet of striated muscle, consisting of two layers crossing each other like the internal and external oblique muscles of the abdomen of mammals. This muscular sheath no doubt serves to compress the air-bladder. No arrangement for its expansion has been detected, and the experiments indicate that the air is forced backward from the mouth into the air-duct, by movements of the jaw, hyoid apparatus, and sides of the mouth similar to those by which water is drawn in and pressed backward in ordinary branchial respiration. While inhaling, the branchial arches are closely approximated, and the opercula are closed.

It is not strange that the anatomical peculiarities above described suggested to authors a respiratory function of the air-bladder. Cuvier and Valenciennes observe [2, 409] that one is led to believe that the organ is not disconnected with the respiration of the fish. Again, [2, 401] in commenting upon the reports that *Amia* is capable of living in the mud and of withstanding deprivation of water, like certain Indian fishes,[5] the same authors suggest that in place of a special apparatus connected with the gills (as in most of those forms), the air-bladder of *Amia* may satisfy the needs of respiration, and add "il faut espérer que de nouvelles observations, et surtout celles que nous sommes en droit d'attendre de l'activité et de la sagacité de M. Agassiz, viendront répondre à ces questions;" [2, 411].

It does not appear that the late Prof. Agassiz made any observations upon *Amia*, or that he connected the exhalation of air, by *Lepidosteus*, with any true respiratory office of the air-bladder; [4, as also quoted by me in 11, 151]. Indeed I am not aware that

[4] It would be easier to speak of these large vessels of the air-bladder as the pulmonary arteries and veins; but this would assume the entire homology of the air-bladder of fishes with the lungs of Amphibia, Reptiles, Birds and Mammals. Fully believing myself in this homology, I think that a much more complete knowledge of the development of the air-bladder its vascular and nervous supply, and the position of the duct, is needed in order to convince some of its morphological identity with the lungs.

[5] Experiments upon several Indian fishes are recorded by Boake [7], Day [8] and Dobson [9].

experiments like those now to be described have been performed with any fish.

That Amia not only exhales, but also inhales air, was indicated by the Peoria observations. Proof of inhalation was obtained in two ways during the present summer.

The fish was placed in a tub of water and a bell-jar full of water was suspended by a cord with its edge just under the surface. When the fish ascended, the jar was moved so as to compel him to rise into it. The exhaled air collected in the top of the jar. The fish, after making apparent efforts to inhale, descended. A few minutes later he ascended and exhaled a smaller amount, then descended as before. At a third ascent, the volume of air in the receiver was decidedly diminished, showing that the fish had inhaled it.

A funnel was then suspended within the jar so that the fish could not reach the air in the top. It was then found that unless the fish was allowed to reach the surface of the water at alternate ascents, little or no air was exhaled.

The conclusion was that the complete respiratory action involved not only exhalation but inhalation.

Experiments are now in progress to ascertain whether the inhaled air is diminished or increased in bulk.

The aerial respiratory actions are more frequent when the water is imperfectly aerated. This was noticed at Peoria. Repeated observations have been since made, but one will suffice as an example.

An *Amia* weighing about 300 grams was placed in about two pailfuls of fresh water, at 7.15 P. M. He did not rise for air until 10.10; then he rose again at 10.37 and 10.40.

Having remained in the same water until the following evening he was observed to rise at 7.45, 7.52, 7.54, 7.57, etc.; the water was then aerated by agitation, and the fish did not ascend for 55 minutes.

The amount exhaled.—This was ascertained by connecting the larger end of a graduated burette with the smaller end of a funnel by means of a rubber tube, and suspending it filled with water, over the fish. The exhaled air, with an example weighing 295 grams, varied from 5½ to 31 cubic centimeters; the average of 23 measurements was 13.

The exhaled air contains carbonic acid.—By means of the funnel and burette, the exhaled air was readily collected for analysis.

The examination of the breath first obtained was made by Instructor W. H. Kent, of the Chemical Department of Cornell University with the following result:

ANALYSIS.	CUB. CENTS. EXAMINED.	PERCENTAGE OF CARBONIC ACID.
1	87.54	3.42
2	85.34	3.39
3	91.54	3.38
	AVERAGE.	3.397

It appeared from this analysis that the breath of *Amia* might contain more than three per cent. of carbonic acid. Now the average per cent. in human breath is only four, and the amount of change with a fish would presumably be less. Moreover, there were reasons for believing that the air first examined did not represent normal breath. In the first place, as the fish descends after inhaling, some of the air, forced backward from the mouth by the approximation of its walls, escapes from the opercular fissure. This "waste" is apt to rise into the receiver and mingle with the breath. The effect of this would be to reduce the percentage of carbonic acid. To avoid including the waste, the funnel was lowered to the bottom as soon as the fish had exhaled and descended, so that when it again rose for inhalation and descended, no escaping bubbles could find their way into the funnel.

In the second place the fish often holds its breath for a considerable time after the usual interval has passed. Breath so held would presumably contain more carbonic acid. In order to obtain normal breath, the fish was observed for some time in order to ascertain the usual respiratory interval in water of given purity. Then, at the close of such an interval, the funnel was moved over the fish. If he ascended and exhaled, the breath was presumed to be normal. But, if, instead of exhaling then, he descended, the experiment was discontinued for the time being. By repeating the experiment at intervals of one or more days, the breath could usually be obtained at the first ascent. But if made more fre-

quently the fish seemed to remember how inconvenient it was to exhale under water without being able to inhale at the same time, and would make many efforts to avoid the funnel.

The normal breath so obtained has been analyzed by Prof. A. A. Brenneman, of Cornell University. He finds always rather more than 1 per cent. of carbonic acid. But much more of the oxygen has disappeared than can be accounted for by that amount of acid. Prof. Brenneman prefers that the analyses already made should be regarded as provisional, and hopes to present full and complete results hereafter.[6]

Since Moreau has found [10] that, with perch slowly asphyxiated in a small quantity of water, all the oxygen has disappeared without the addition of a corresponding amount of carbonic acid, we may infer that with *Amia* the gas is partly excreted by the gills.

Amia displays great powers of endurance of deprivation of water. On one occasion a fish was kept out of water for an hour and five minutes without apparent discomfort or injury. During most of the time the opercula were tightly closed, but there were regular movements of the jaw, hyoid apparatus and sides of the mouth. Upon this matter of endurance experiments are still in progress. Meantime it is to be noted that since the air-bladder can receive blood only through the gills, these latter must be kept constantly moist.

Many other experiments suggest themselves, and will, in course of time, be performed.

The water itself should be examined before and after the fish has lived in it for a certain time.

The blood carried to and from the air-bladder must be observed as to color and composition, and amount both when inhalation is frequent, and at longer intervals.

By using two funnels, one for exhalation, and one for inhalation, much may be ascertained as to the relative amounts exhaled and inhaled, and the changes which are brought about in the body.

By securing the opercula, and introducing a tube through the mouth into the air-bladder, artificial respiration may be carried on.

[6] It is proper to state that the fish eat little or nothing during several weeks of these experiments. In the absence of the cray-fish, which seem to be its usual food, the little crabs found in oysters are readily taken by *Amia*. A small example also took bits of chicken's liver. Both large and small readily devour tadpoles.

When *Amia* is kept out of water, the vessel should be closed, and the air analyzed. The air-duct should also be closed in order to determine how far the moist gills alone are capable of carrying on respiration.

It is obvious that for the convenient performance of these and other experiments a fish must be of a moderate size, hardy, and indisposed to bite.

All these advantages are presented by the Amia, and I suggest to those who live where the fish is abundant the complete investigation of its habits, as well as of its development concerning which at present nothing is known, the smallest example hitherto obtained being 5 cm. (about 2 inches) in length; (12,261, and fig. 1).

SUMMARY.

1. Amia has a large, cellular, and vascular air-bladder, and a large air-duct.

2. The afferent vessel upon each side is formed by the union of half the third epibranchial vessel, with the entire fourth epibranchial. The trunk so formed is as large as either the aorta or cæliac artery.

3. The efferent vessel on each side opens into the sinus of Cuvier, nearer to the heart than the cardinal vein.

4. That the air-bladder of Amia might be employed for respiration, has been suggested by Cuvier and Valenciennes, and others, but no experiments seem to have been recorded.

5. Exhalation of air is obvious. Inhalation is proved in several ways.

6. Air is probably inhaled by first enlarging, then suddenly diminishing the capacity of the mouth. Exhalation is probably due to the contraction of the sheath of striated muscle on both sides of the air-bladder.

7. The amount of air exhaled by a medium sized fish (about 300 c.m. long) varies from $5\frac{1}{2}$ to 31cc.; the average of 23 measurements is 13 cc.

8. The exhaled air (of a fasting fish) contains at least 1 per cent. of carbonic acid. The deficiency of oxygen suggests that some more acid is excreted by the gills.

9. The aerial respiratory actions vary in frequency according to the degree of aeration of the water. In very stale water the intervals are about three minutes.

10. Amia withstands deprivation of water longer than ordinary fishes. It is hardy and gentle, hence peculiarly adapted for experimentation.

LIST OF WORKS AND PAPERS REFERRED TO.

1. LINNÆUS: Systema Naturæ. Editio duodecima, reformata. 1766.

2. CUVIER, G., and VALENCIENNES, A.: Histoire naturelle des poissons. 1846.

3. CUVIER, G.: Le Regne animale.

4. AGASSIZ, L.: Young garpikes from Lake Ontario. Proc. Boston Society of Natural History. 1856, vi, 48.

5. FRANQUE, H.: Amia calvæ anatomiam descripsit tabulaque illustravit; folio, pp. 12, 1 plate. 1847.

6. DUMÉRIL: Histoire naturelle des poissons. Ganoides, Dipnoans, Lophobranches. Paris, 1870.

7. BOAKE: On the fishes inhabiting the Ceylon marshes. Journal of the Ceylon branch of the Royal Asiatic Society, 1865.

8. DAY, F.: Observations on some of the fresh-water fishes of India. Proc. Zool. Soc. of London, May 14, 1868; 274–288.

9. DOBSON, G. E.: Notes on the respiration of some species of Indian fresh-water fishes. Proc. Zool. Soc. of London, May 19, 1874; 312–321.

10. MOREAU, A.: Recherches expèrimentales sur les functions de la vessie natatoire. Annales des sciences nat. Tome iv, 1876, pp. 85, 2 plates.

11. WILDER, B. G.: Notes on the N. A. Ganoids. 1. On the respiratory actions of *Amia* and *Lepidosteus*. Proc. Am. Asso. Adv. Sci., 1875; 151–153.

12. WILDER, B. G.: On the serrated appendages of the throat of Amia. Proc. Am. Asso. Adv. Sci., 1876; 259–263

13. WILDER, B. G.: On the tail of Amia. Proc. Am. Asso. Adv. Sci., 1876; 264–266.

14. MILNE-EDWARDS, H.: Leçons sur la physiologie et l'anatomie comparée de l'homme et des animaux. Tome deuxième, 1857.

TITLES OF OTHER PAPERS READ IN SECTION B.

On the Original Connection of the Eastern and Western Coal-fields of the Ohio Valley. By N. S. Shaler, of Cambridge, Mass.

On the Geographical and Geological distribution of the genus Beatricea, and of certain other fossil corals in the rocks of the Cincinnati group. By N. S. Shaler, of Cambridge, Mass.

On the Recent Formation of a small Anticlinal axis in Lincoln County, Kentucky. By N. S. Shaler, of Cambridge, Mass.

The Structure of Eruptive Mountains. By J. W. Powell, of Washington, D. C.

Overplacement. By J. W. Powell, of Washington, D. C.

On Sex in Flowers. By Thomas Meehan, of Germantown, Pa.

The Law of Repetition. By Miss Virginia K. Bowers, of Altenburg, Mo.

On the Geodes of the Keokuk Formation and their characters as Casts of Sponges; with descriptions of the Genus Biopalla and several species. By Samuel J. Wallace, of Keokuk, Iowa.*

Atmospheric Concussion as a means of Disinfection. By Mrs. H. K. Ingram, of Nashville, Tenn.

On the Relation of Organ to Function; or of Form in General to Mode of Energy received and exerted. By R. L. Kirkpatrick, of Knoxville, Tenn.

* This paper is printed in Amer. Jour. Sci. Art. Vol. XV, 1878.

Our Knowledge of the Cotton Worm. By A. R. Grote, of Buffalo, N. Y.

On the Fibre of the Cotton Plant, considered with reference to a practical application of Machinery to its Manufacture. By James A. Ridley, of Nashville, Tenn.

On the Silurian Island of the Cincinnati Uplift, with reference to its part in Tennessee. By Jas. M. Safford, of Nashville, Tenn.

On the Continuation of the Folds of the Alleghany Chain, to the north of the Delaware River. By N. S. Shaler, of Cambridge, Mass.

On the Origin of Structural Variation. By E. D. Cope, of Philadelphia, Pa.

On the characters of a new Cretaceous Saurian from the Rocky Mountains. By E. D. Cope, of Philadelphia, Pa.

The Variation of Certain Fresh Water Mollusks of the United States, and their Geographical Distribution. By A. G. Wetherby, of Cincinnati, Ohio.

Notice of a specimen of Cyrtodonta ventricosa from the Lower Silurian. By Jas. M. Safford, of Nashville, Tenn.

On the use to be made of the Post Route Maps in the advancement of science. By B. S. Hedrick, of Washington, D. C.

A Section of McKinney Hill, Tennessee. By E. L. Drake, of Nashville, Tenn.

Geological position and mode of Origin of Hydrated Brown Oxide of Iron. By E. T. Cox, of Indianapolis, Ind.

All Life Conditionally Immortal. By Wm. Bross, of Chicago, Ill. (Read in General Evening Session.)

PERMANENT

SUBSECTION OF ANTHROPOLOGY.

ADDRESS

OF

PROFESSOR DANIEL WILSON,

CHAIRMAN OF THE SUBSECTION OF ANTHROPOLOGY.

LADIES AND GENTLEMEN:—

THE honor which you have conferred upon me in electing me chairman of the subsection of Anthropology, imposes on me the duty of delivering an opening address on some subject relating to the special objects of study to which your researches are directed. I greatly regret that the protracted effects of an accident, from which I am still suffering, have prevented me giving the requisite time and study to the preparation of an address worthy of the subject, and of the audience to which it has to be presented. I must, therefore, throw myself on your kind indulgence, and trust that the varied character and high interest of the papers to be communicated to this subsection, will atone for all deficiencies at its opening.

By the establishment of a permanent subsection of Anthropology in the A. A. A. S., the growing importance of this attractive department of science has received a just recognition, which cannot fail to give fresh stimulus to research. In its most comprehensive aspects Anthropology includes the old-fashioned labors of the antiquary in their later development into a science of Archæology; it embraces all that pertains to that common ground of the geologist and archæologist in the more recent strata in which man and

the traces of his primitive arts are believed to occur in situ; yet at the same time it deals mainly with a class of evidence peculiarly its own. The extinct life of geological periods reveals itself to the instructed eye of the palæontologist chiefly by means of the actual fossil remains. Or if to these have to be added illustrations of habits, food, structure, etc., such as are supplied by means of gnawed bones in the cave-resorts of carnivora, coprolites, footprints, and the like subsidiary evidence: still all are traceable directly or indirectly to the living organism. But with man it is otherwise. His presence is manifested as the contemporary of such ancient life, independently of all traces of his actual remains by means of the works of his hands; and thus the study of the archæologist becomes an ingenious process of induction, when employed to determine the social habits, the culture, and the intellectual and moral characteristics, of races of men which had passed away long before the very dawn of history. But the science of Anthropology also comprehends the common ground of biology and physiology, in which man takes his place along with all other animals, as a subject of natural history. The physical structure of the savage as compared with civilized races, and of the oldest osteological traces of man with both, are legitimate subjects of investigation. Craniology, and other branches of comparative anatomy, in like manner come under review, first in the comparison of races, in reference to the diverse varieties of man; and next in the study of the analogies of the Anthropomorpha with the Anthropidæ, as represented by the single genus and species Man.

In the older classifications of the naturalist, the aim has been to determine for Man a place in the system of nature which shall give distinct recognition to his moral and intellectual, as well as to his physical attributes. The Bimana of Cuvier and Blumenbach, and other schemes of a like kind, which for the present have fallen into disfavor, had this in view. But while it is legitimate for the naturalist in treating of man as a vertebrate animal, to take into consideration his physical structure alone; it is not only not unphilosophical to look beyond this to the physical elements of his being; but it is indispensable, that the anthropologist ever keep in view the double nature of man. That man is an animal is unquestionable; but that he is something more is assumed in the very simple axiom which constitutes the basis of the whole argument for the antiquity of Man. The constructive instincts of

beast, bird, crustacean, insect, and zoophyte, furnish endless subjects for admiring study; yet so thoroughly is the use of tools recognized as the exclusive attribute of man, that the discovery in the glacial drift, or cave-breccia, of a single artificially fashioned flint or stone — chipped though it may be into rudest form — is sufficient to satisfy the geologist of the contemporaneous presence of man. Hence, while it is convenient to keep apart from the elements of physical structure all those evidences which relate to mental phenomena, a very inadequate conception of man must be formed if the latter are excluded from our estimate of him.

But it is one of the curious and unexpected results of the great revolution in biological science consequent on the recognition of a continuity of succession of forms of life, as based on the hypothesis of evolution, that such distinctive elements of mental phenomena as are embraced under the heads of psychology, sociology, etc., are no longer absolutely limited to man. In the comprehensive inquiries to which the novel teachings of evolution have given rise, the germs of man's intellectual and moral, as well as of his physical attributes, are being sought for in the instincts and habits of the lower animals: and the phenomena of social life which they exhibit have acquired a novel interest from their supposed bearing on the sources of highest mental and moral development.

The result of such researches tends more and more to diminish the number of characteristic attributes previously adduced as the basis of a true definition of Man. Blumenbach reduced his earlier and more comprehensive characteristics into the two very simple elements of the "*animal erectum, bimanum.*" But the order of Bimana, subsequently adopted by Cuvier for the human family, is already rejected, in spite of such high authority. Owen, again, — looking to the brain as the organ of Man's grand inheritance, reason, — sought to determine for him a classification distinct from the other Primates, and from the Mammalia generally, under the term Archencephala; but the proposed sub-class, after protracted discussion among the most eminent anatomists and physiologists, has in like manner been abandoned.

It thus becomes ever more difficult to select the special characteristics which shall supply a definition exclusively applicable to Man. He has been styled the tool-using, and the tool-making animal; the fire-using animal; the cooking animal, etc. There

is one attribute which still seems to be his right; and which pertains to the source of all those differentiations. We popularly use such terms as the irrational creation, the brute creation, rational beings, etc.; accepting reason as the primary distinctive characteristic of Man. Yet even in this he is now denied an exclusive heritage; nor is it now, for the first time, that some exercise of a reasoning faculty is recognized as pertaining to the lower animals. Physically, mentally, and morally, the ground within which he has seemed to be intrenched beyond reach of encroachment by the lower orders of animate nature, seems to give way. But there remains one specialty indisputably his own. We habitually designate all other living creatures as *dumb* animals; discriminating in this between the inarticulate cries of the lower animals, and the intelligent utterances of human speech. Hence the legitimate selection of language as the most essential and unvarying index of Man. No race of men has ever been found devoid of language. No other animal has ever been known to possess language in its most rudimentary form. We have, indeed, speech in a certain sense, in the parrot, the starling, etc.; but this is no more than another phase of the capacity for imitating sounds, familiar to us in the natural imitations of the mocking bird, and dependent in part on physical structure. Neither in the one case nor in the other, are the sounds symbols of thought, or vocal signs of objects or ideas.

Hence one of the highest branches of Anthropology is the Science of Language. The researches into the sources and nature of speech, and into the Science of Language, which have been pursued by the foremost among the philologists of Europe for upwards of half a century, have opened up novel lines of inquiry not less fascinating than the most brilliant discoveries of the age. But America has its own special department in this great work, in the languages of a continent, isolated for unnumbered centuries; and left to develop its own philological characteristics uninfluenced by any of the sources which have affected the structure of languages of the Old World within the historic period.

Professor Max Müller has drawn attention to the tendency of the languages of America towards an endless multiplication of distinct dialects. Those again have been grouped by the synthetic process of Hervas into eleven families; seven for our northern continent, and four for South America. But much yet remains to

be done in this important department. One able English comparative philologist, Mr. Hyde Clarke, invites attention to a singularly fascinating line of research, in his "Khita and Khita-Peruvian Epoch." Tracing the progress of his Sumerian Race — from the union of which with the Semites he derives the ethnological peculiarities of the Jews,— he assigns an interval of four thousand years since their settlement in Babylonia and India. In like manner, on the assumption of their migration from a common centre in High Asia, which the division of Western and Eastern Sumerian in pronouns and other details is thought to indicate; it appears probable that Peru may have been reached by a migratory wave of earliest movement from four to five thousand years ago; though Mr. Hyde Clarke conceives that it is quite within compass that the same great wave of migration, by which India and Babylonia were reached, continued to propagate its centrifugal force; and by its means Peru was reached within the last three thousand years.

The system of Agassiz, based on his idea of natural provinces of the Animal World, and their relation to different types of Man, favored the idea of various native American centres within which the diverse varieties of American Man originated; and from whence they had been distributed over the entire continent. This idea proved acceptable for a time to American ethnologists, advanced as it was on such high authority, and with some specially seductive arguments in its favor. But the progress of science has effected a total revolution in reference to this question. The idea of a plurality of origin, and of a number of distinct races of Men, was in harmony with the popular process of an endless multiplication of species throughout the entire animal kingdom. Hence it found favor for a time in the speculations of science, and was even dogmatically advanced as one of its indisputable truths. But already the leadings of scientific induction point in a wholly different direction, tending to the more comprehensive unity which embraces all men in the descent from a centre common to them with other animals.

It is sufficient for our present purpose to note that the abrogation of a system which recognized in the Man of America a being primarily distinct in origin from all races of the Old World, leaves us free to follow out the interesting inquiries suggested by apparent relations between the native languages of this continent and

those of ancient Asia and Africa, unencumbered by conflicting elements of scientific classification. Assuming, for the sake of argument, that a common Turanian population of Asia and America separated, let us say, four thousand years ago: the phenomena exhibited in the extreme polysynthetic characteristics of many of the native languages of this continent as compared with the agglutination of the Turanian languages of Asia, furnish a subject of investigation not less interesting to American students, alike of the Science of Language, and of the whole comprehensive questions which Anthropology embraces, than the relations of the Romance Languages of Europe to the parent Latin; or of the Latin itself, and all the Aryan languages, ancient and modern, not only to the Sanskrit and Zend, but to the indeterminate stock which furnished the parent roots, the grammatical forms, and that whole class of words still recognizable as the common property of the whole Aryan family of languages. The Sanskrit was a dead language three thousand years ago; the English language, as such, cannot claim to have originated much more than fourteen centuries ago, yet both partake of the same common property of numerals and familiar terms existing under certain modifications in Sanskrit, Greek, Latin, German, Slavonic, Celtic, Anglo-Saxon, and in all the Romance Languages of Europe. What has America to show, analogous to this: not only of affinity of languages within itself, but of possible relationship to languages of other continents, and of elder centuries?

Gallatin early drew attention to certain analogies in the structure of Polynesian and American languages, as deserving of careful investigation; and pointed out the peculiar mode of expressing the tense, mood, and voice of the verb, by affixed particles, and the value given to place over time, as indicated in the predominant locative verbal form. The substitution of affixed particles for inflections, especially in expressing the direction of action in relation to the speaker, is common to the Polynesian and the Oregon languages, and also has analogies in the Cherokee. We have, in truth, to deal with language as the geologist has learned to do with the earth's crust, and recover from the aggregations of the one, as from the accumulated strata of the other, the records of a long forgotten past. Subsequent observations, though hitherto very partially prosecuted, have tended to confirm the idea of elements recognizable as common in the languages of Polynesia and

America. This is specially noticeable in relation to the languages of South America, as shown in their mode of expressing the tense of the verb; in the formation of causative, reciprocal, potential and locative verbs, by affixes; and in the general system of compound word structure. The incorporation of the particle with the verbal root appears to embody the germ of the more comprehensive American holophrasms. But here again while seeming to recover links of connection with Polynesia, it becomes apparent, as such affinities lead us to anticipate, that we are on the track of others no less clearly Asiatic. Striking analogies have been recognized between the languages of the Deccan, and those of the Polynesian group, in which the determinate significance of the formative particles on the verbal root, equally admits of comparison with peculiarities characteristic of languages of this continent. On this subject the Rev. Richard Garnett remarks, in a communication to the Philological Society, that most of the native American languages of which we have definite information, bear a general analogy alike to the Polynesian family and to the languages of the Deccan, in their methods of distinguishing the various modifications of time; and he adds: "We may venture to affirm in general terms that a South American verb is constructed precisely as those in the Tamul and other languages of Southern India; consisting, like them, of a verbal root, a second element defining the time of the action, and a third denoting the subject or person."

Such indications of philological relations outside of the American continent, are replete with interest. If the languages of South America have such affinities with the Polynesian archipelago, then also we may expect to establish a like relationship between the megalithic sculptures and cyclopæan masonry of Peru, and the remarkable ancient stone structures and colossal sculpture long ago noted by Captain Beechy on some of the islands nearest the coasts of Chili and Peru; and since then recognized on others lying towards the Asiatic Continent. We thus seem to recover the trail of an ancient migration from Asia to America, of which other traces are not wanting: as in the Polynesian practice of compressing the skull, as described by Dr. Pickering, and since abundantly confirmed by the forms of Kanaka skulls. By following up the traces of this strange custom, perpetuated among the tribes on the Pacific coasts both of Northern and Southern America to our own day, we retrace the steps of ancient wanderers back-

ward through the islands of the Pacific, to Asia; and so to elder centuries when the Macrocephali of the Euxine attracted the observant eye of Hippocrates; and became familiar to Strabo, Pliny, and Pomponius Mela.

The evidences of migration from the continent of Asia to the islands of the Pacific are abundant, and some of them seemingly of no very remote date. The direct relationship of existing Polynesian languages is not Mongol but Malay; but this is the intrusive element of a time long subsequent to the growth of that linguistic element which still perpetuates traces of Polynesian and American affinities. The number and diversity of the languages of this continent, and their essentially native vocabularies, prove that the latter have been in process of development from a remote period, free from contact with languages which appear to have been still modelling themselves according to the same plan of thought in many scattered islands of the Pacific.

In attempting to recover the traces of ancient history thus indicated, the languages which seem to invite special study are the Aymara, the Quichua, and the Maya. The Quichua was the classical language of South America, wherein, according to its native historians, the Peruvian chroniclers and poets incorporated the national legends; and which occupied a place under Inca rule closely analogous to that of the Norman French in England, from the eleventh to the thirteenth century. The Maya language, which strikingly contrasts, in its soft vocalic forms, with the language of the nations immediately to the north of its native area, is that which Stephens tells us was affirmed by Indian traditions among the natives of Central America to be still spoken by a living race in the region beyond the Great Sierra, extending to Yucatan and the Mexican Gulf. To those ancient cultured languages of the seats of an indigenous civilization on this continent, attention must be directed anew, with all the latest appliances furnished in the new developments of the science of language. There, apparently, we have to look for an answer to many inquiries specially interesting to ourselves as occupants of this western world. If the arts of architecture and sculpture, and the hieroglyphic records with which they are enriched, are modifications of prehistoric Asiatic civilization, it is there that the evidence is to be looked for; and if the arts of the sculptor and architect were brought to this continent by wanderers from an Asiatic fatherland, then the

arts of the potter and of the metallurgist are also an inheritance from the old Asiatic hive of the nations, that long-recognized cradle-land of the human race.

In searching for the origin of the peculiar native civilization of America, Mr. Hyde Clarke employs philology as his chief guide. He takes the recently deciphered Akkad for the typical language of his Sumerian class. This he assumes to have started probably from High Asia, and to have passed on to Babylonia; while another branch diffused itself by India and Indo-China, and thence by way of the islands of the Pacific reached America. Hence in an illustrative table of Sumerian words arranged under four heads, as Western, Indo-Chinese, Peruvian, and Mexican, etc., he remarks "while in some cases a root may be traced throughout, it will be seen that more commonly the Western and American roots, or types, cross in the Indo-Chinese region." But he also recognizes another, and older influence, related to the Agaw of the Nile region, of which he discovers traces in the Guarani, Omagua, and other languages of South America; indicating evidences of more remote relations with the Old World, and with the African continent; but which he conceives to have been displaced by a Sumerian migration by which the Aymara domination was established in Peru, and the Maya element introduced into Yucatan. Those movements are assumed to belong to an era of insular and elder Asiatic civilization, during which the maritime enterprise of the Pacific may have been carried on upon a scale unknown to the most adventurous of modern Malay navigators, notwithstanding the essentially maritime character by which the race is still distinguished.

Thus the highway to the Pacific was familiar to both continents; and hence a second migration is recognized in certain linguistic relations between the Siamese and other languages of Indo-China, and the Quichua and Aztec of Peru and Mexico. Here at any rate are glimpses of research in the prosecution of which American Anthropologists may employ their learning and acumen with results which shall reveal to us a past not less marvellous, and possessing a more personal interest, than all which geology has recovered from the testimony of the rocks. This is one of your legitimate lines of investigation, singularly fascinating in its rich promises. Already the students of science are recovering for us curious glimpses of that long-forgotten era when the parent language of the

whole Aryan stock was the tongue of an ancient civilized people, on the great plateau of Central Asia, speaking a language which was neither Sanskrit, Greek, German, nor Slavonic; but which included the dialectic germs of all. In the remote era to which this points, the parent stock of primitive Aryans had realized that fundamental idea of settled civilization which consists in property in land; had made great progress in agriculture; and as Professor Max Müller says of them, "they had recognized the bonds of blood, and sanctioned the bonds of marriage; they invoked the Giver of Light and Life in heaven by the same name which you may still hear in the temples of Benares, in the basilicas of Rome, and in our own churches and cathedrals." The same lines of research point hopefully to future disclosures for ourselves, helping us to bridge over the great gulf, which separates America from that elder historic and prehistoric world; and so to reunite the modern history of this continent with an ancient past.

Many other departments of our comprehensive study might in like manner be alluded to. I might fitly refer to the undesigned, yet exhaustive ethnological experiments which are being carried out on this continent on the grandest scale. Here we witness the transferrence of the indigenous population of Africa, of Asia, and of Europe, to a continent where they are brought into new geographical, climatic, and social conditions. We see the African in the south, the Chinese on the Pacific, the Frenchman on the St. Lawrence, the German, the Celt, and the Anglo-Saxon, all subjected to novel influences, necessarily testing the results of a change of climate, of diet, and of social habits, on the ethnical character of each. Here too, alike in the Red and Black races, we see experiments of hybridity carried out on a scale adequate to determine many points involved in the question of the origin and perpetuation of the various races of mankind. Here, too, man can still be studied, as among the Esquimaux, in a condition closely analogous to that which is ascribed to postpliocene, if not to preglacial man. Here may still be seen races practising neolithic arts of a stone age as genuine as that of Europe's prehistoric times; on the other hand, we witness influences begotten by the abrupt intrusion of the matured arts of Europe on the first crude efforts of the native savage with the virgin copper which he has learned to hammer into weapons and implements to supply his needs. Here, too, may be seen the infantile rudiments of ideog-

raphy and letters in the symbolic picturings of the Indian on his buffalo robe or his grave post; and, beyond this the transitional stages of a written language, through the pictorial records of Mexico, the hieroglyphics of Central America, and even the first approximations to true numerals and alphabetic characters. In all this I but glance at some of the most salient points embraced within the legitimate work of this section.

It is thus apparent that the department assigned to the anthropological subsection embraces an ample and varied field in which very diverse talents and acquirements may be brought into coöperation; and made to converge by widely separated lines of thought and research, towards the common centre of great and far-reaching truths involved in the science of Man. So comprehensive a field of study demands for its elucidation the mastery of many distinct branches of science, and a comprehensive knowledge both of ancient and modern languages. The researches of the scholar in his study, of the archæologist and geologist in their field-labors, of the traveller in his far-wanderings and of the missionary teacher in his more intimate intercourse with the nations of strango lands, have all to be combined with investigations in other departments of science; while physiology, palæontology, and comparative anatomy, mineralogy and metallurgy, each contributes its quota towards the interpretation of the evidence with which the anthropologist has to deal.

But various causes have thus far combined to give to the investigations of the American anthropologist a character essentially distinct from that which has marked those of his co-laborers in Europe. In the earlier stages of research he has seemed in some respects to be placed at a disadvantage. In reality, however, as the special features which pertain to such inquiries on this continent are fully matured, it will become apparent that he enjoys many advantages, and has within his reach some exclusive facilities which may be expected to give a unique character to American anthropology. Whether our object be to study the characteristics of savage man unaffected by extraneous influences of civilized nations; to investigate the effect of the intermingling of essentially diverse races, in the production and perpetuation of new varieties; or in the improvement, degeneracy, or sterility of such hybrid stocks; to ascertain the condition of races ignorant of metallurgy; to trace the processes by which the true metal-

lurgic arts have been evolved, from the first crude working of malleable copper or lead with the hammer, to the tentative intermingling of copper and tin in the crucible, and the moulding and casting implements and personal ornaments of bronze, as well as of gold; or lastly, to follow in the steps of Humboldt, and investigate the analogies to ancient Asiatic beliefs in the mythology of the semi-civilized nations of Central and South America; the indications of correspondence in their calendars and astronomical divisions of time; or the affinities of grammar recognizable in languages of the New and Old World: in each and all of those it will be found that we enjoy, as occupants of this continent, facilities peculiarly our own.

Our training for the work which this Anthropological subsection has undertaken is of itself peculiar. The archæologists of Europe had been busied for centuries in the elucidation of early historic monuments; and only during the present century passed beyond that stage to a study of the ruder traces of primitive art, and of the physical characteristics of unhistoric, if not prehistoric races. The researches directed to the elucidation of the problems thus originated were followed up through medieval, classical, Assyrian, Indian, and Egyptian remains, to the very threshold of that prehistoric period which forms the debatable land between geological and historical epochs. Indeed, not the least significant fact in reference to the remarkable disclosures of the past quarter of a century is that some of the most characteristic drift implements, such as the flint spear-head found alongside of a fossil elephant's tooth, in the vicinity of Gray's Inn Lane, London; or the large flint implements of the same type from the drift of the Waveney Valley, at Hoxne in Surrey, underlying similar fossil remains, had been brought under the notice of archæologists, and deposited in the British Museum, upwards of a century before the idea of the contemporaneous existence of Man and the mammals of the drift found any favor.

The conception of the comprehensiveness even of historical antiquity was long trammelled in Europe by a too exclusive devotion to Greek and Roman remains; or by profitless efforts at the interpretation of the more ancient monuments of Egypt; but the historical relations of this continent with the Old World are so recent that for us the fifteenth century is its historical dawn; and anything dating before the landing of Columbus has till very recently

seemed to be inconceivably ancient. Hence antiquarian speculations and historical research have been almost exclusively occupied on matters of a very modern date; and great industry has been often profitlessly expended in attempts to establish derivative relations between the sculptures and hieroglyphics of Central America, Mexico, and Peru, and those of ancient Egypt. But in this, as in so many other departments of the archæology and ethnology of the New World, we want facts rather than theories. Much has been done in recent years to add to our knowledge of the antiquities of Central America and Peru. Forbes, Markham, Agassiz, Hutchinson, Squier, and others, have made important additions to the evidence required. Nevertheless even now it is a mooted point whether Central America has not yet to disclose, not only still more remarkable ruined cities than any that Stephens revealed, but even inhabited cities where a native civilization is still in progress.

But the all-absorbing theme of archæological inquiry at present embraces the evidence of the antiquity of Man. The palæolithic disclosures of the French drift belong to our own day; and though the researches of Mr. MacEnery in the famous Kent's Hole Cave had, fully half a century ago, brought to light true palæolithic flint implements in the same red loam with the bones of the Mammoth, Tichorhine Rhinoceros, Cave Bear, and other extinct mammalia, it is only now that the true significance of the disclosures of the ossiferous caves of Europe is being understood. America was indeed little behind Europe in the earlier stages of cave research, for it is now upwards of forty years since Dr. Lund and M. Claussen recovered from limestone caverns in the Brazils, the remains of Man alongside of many fossil bones of extinct mammals; and — with special significance in relation to more recent speculations — including those of extinct genera of fossil monkeys.

It is not necessary that I should now detail the isolated and dubious illustrations of American palæolithic art which have thus far rewarded zealous research. Flint implements from the auriferous gravel of California were produced at the Paris Exposition of 1855; and have since been described among the disclosures of the drift in Illinois, Georgia, and California. Still more, from the auriferous drift of the latter state there has been produced to you in previous years, not only a highly polished stone plummet, but

the far more startling disclosure of a complete human skull. I shall not now enter on a discussion of the scientific value of such evidence. Chance-found, isolated examples of flint implements must ever be received with caution, as evidence of palæolithic art, on a continent where the indigenous population have not even now ceased to manufacture tools and weapons of flint and stone. The striking feature of archæological exploration in Europe has been that the tool-bearing drift has been determined by its geological characteristics; and the traces of Palæolithic Man are now sought for with the same confidence as the well recognized fossils of any geological strata.

To this same stage of geological and archæological systematic research we have now happily arrived in America; and I may presume that at your present meeting an opportunity will be afforded of judging of the significance of the highly suggestive discovery of Dr. Chas. C. Abbott, in the drift of the Delaware River Valley, at Trenton, New Jersey, already produced in the Report of the Peabody Museum of American Archæology and Ethnology for the present year. You have there set forth the discovery of data from which it is assumed that man may be shown to have existed on this continent during the process of formation of the great gravel deposits, now ascribed to glacial action, which extend from Labrador as far south as Virginia, and are but one of the many indices of the Ice Age of this Western Hemisphere. The great importance which attaches to the discoveries now referred to, is due to the fact that they are the result of systematic research, based on the scientific analogies of European archæology. The locality selected for this investigation is the valley of the Delaware, at Trenton, N. J. There, Dr. Abbott has found, in situ, rude stone implements formed of a granular argillite, which he believes "were fashioned by man during the glacial period, and were deposited with the associated gravels as we now find them." The implements are of peculiar form, due in part to the material of which they are fashioned. To the most characteristic of these Dr. Abbott gives the name of the "turtle-back celt." But besides this class of rudely chipped stone implements, were also discovered one or more flint spear-heads, to which a like antiquity is ascribed. Judging from its material, size, and configuration, as indicated in the published report, the question of the contemporaneous origin of the figured spear-head appears to me to require

careful consideration. Assuming, however, that the whole evidence will be submitted to the section, it is sufficient that I now refer to a subject which cannot fail to receive adequate attention from those best qualified to determine the true significance of the evidence adduced.

It is an event which may be hailed as a good omen for this anthropological department of the scientific work of the Association, that the Peabody Museum of American Archæology and Ethnology is able to produce such practical fruits of the wise patronage which it is enabled to extend to archæological research. We are but on the threshold of this young science, pregnant with marvellous disclosures relative to the history of man. Let us not be hasty in the acceptance of crude theories, nor rash in the needless overthrow of old waymarks in the progress of knowledge. There is a danger at the present stage, of our becoming enamoured of theories just in so far as they conflict with hitherto received opinions, or charm by reason of the vastness of their assumptions. Opinion is advancing with rapid strides. There is a danger that fancy shall far outspeed fact. I can remember the time when, in the British Association for the Advancement of Science, the idea of races in Britain prior to the Celtæ, was scouted with scarcely disguised contempt. Now the tendency is to look upon the assumed traces of fossil man in the Tertiary deposits, as comparatively recent. On any hypothesis of evolution, which includes man they must indeed be so; for the most ancient well-authenticated human crania thus far discovered help us in no degree to the recovery of any anthropomorphic stage of intermediate transition from lower forms of life. The Cro-Magnon skulls of the French Reindeer period exceed, rather than fall short of, the cerebral capacity of the average modern Frenchman; nor is the famous Neanderthal skull, with its enormous superciliary arches,—so suggestive of analogy to the anthropoid apes,—by any means deficient in indications of cerebral development. We stand in need of ampler evidence, not of more comprehensive hypotheses. The latter cannot be received with too great caution. Our duty is, while honestly and fearlessly accepting whatever evidence may offer, and following out the leadings of truth to whatever results they may tend, to guard carefully against the adoption of hasty assumptions. We have first to establish beyond all doubt the facts of science; we must next be sure that our inductions follow logi-

cally from such premises. The construction of startling hypotheses is at no time a matter of difficulty. It is otherwise with the patient, diligent accumulation of all the evidence on which a sound scientific induction can alone be based. The truths which we are now in search of specially demand from us the elimination of all uncertain, still more, of all spurious or misleading elements. Truth, whatever it may be, must triumph in the end ; and whatever tempts us to neglect the calm, philosophic spirit of inductive research will only retard that triumph. The work before you for years to come must be the accumulation of evidence, the cautious sifting of it in all its bearings, and the ascertaining what its teachings really are. The work which has thus to be done is laborious ; but the truth when finally established will bring with it its own abundant reward.

PAPERS READ.

Additional Facts concerning Artificial Perforation of the Cranium in Ancient Mounds in Michigan. By Henry Gillman, of Waldo, Florida.

In my paper entitled "The Ancient Men of the Great Lakes," read before the Detroit Meeting of the American Association (August, 1875), brief mention is made, in a supplementary note, of a remarkable skull from a mound at Devil River, Michigan (Lake Huron) in connection with the presentation of two rough diagrams exhibiting the peculiarities of the skull, and the position and dimensions of the perforation by which it is distinguished.

It will here be only necessary to say that this peculiar and exceedingly narrow cranium is imperfect, all of it except the upper portions of the frontal and parietals being wanting; that it affords the extraordinary low cephalic index of .557, the breadth being exactly 4.07 inches, the length, 7.30 inches; while the lengths of frontal and parietal are respectively 5.10 and 5.00 inches, and the breadth of the frontal, 4.52 inches. The parts of the skull which remain are in an excellent state of preservation; and I may add that the perforation, instead of being circular, like that of all the other perforated skulls from our mounds which I have seen (with one exception, to which I shall presently refer), is elliptical in outline. The diameters of the perforation are 0.8 and 0.7 inch, and as if to heighten the narrow appearance of the skull, the greater diameter is latitudinal. The perforation, as is without exception the case in all of our skulls bearing this distinction, occupies a central position at the top of the head. It is placed upon the sagittal suture, which is also invariably the case except where the junction of the sagittal and coronal sutures occupies the summit of the vertex, when the incision is made at the junction.

Though all attempts to arrive at the precise significance of this curious custom of perforating the top of the head after death have hitherto been attended with most perplexing doubts, the various opinions oscillating between the two extremes of whether the

strange observance was intended as a distinguished mark of honor bestowed on a beloved or illustrious individual, or the stigma of disgrace attached to the hated and overwhelmed enemy; for several reasons I have from the first inclined to the belief that this burial ceremony was reserved for the esteemed or exalted dead.

The mound at Devil River, I have learned through the Rev. Mr. Pilcher, was formed of sand, and was of an irregular conical shape. It was from ten to fifteen feet high above the surrounding land, the soil of which is gravelly. From this mound, within two or three feet of the surface, five skeletons of men were exhumed, all with perforated skulls, and having been buried in a standing posture. Unlike the burials in the Sâble River mounds, the other bones as well as those of the crania were present. Beneath the remains of those five individuals, and at the level of the base of the mound, and occupying a central position, occurred a single isolated interment — that of an adult man. To this skeleton, which was extended on its back, with the head to the north, belonged the perforated cranium we are noticing, and which I have designated as the Devil River skull.

Here, then, we have an example of an individual so revered, or of such rank as to be entitled to, or to have accorded to him at his death, the special distinction of having a memorial-mound erected over his remains. It follows, that the perforation which we find marking his skull could scarcely have been intended as other than an additional tribute of respect; and is an evidence that unusual reverence had been shown him in his funeral rites. At any rate, in this case it cannot be regarded as the stigma of dishonor. The five subsequent interments, the cranium in each instance bearing a like distinction, are but a further corroboration of this. We know that a mound erected, as was this one, to the honored dead, was, even to a long subsequent period of time, regarded as peculiarly sacred; and to be interred therein was unquestionably a mark of consideration which must have been eagerly coveted for the deceased by his surviving friends.

The mound at Sâble River, Michigan, from which was exhumed so large a number of perforated skulls, affords evidence which can only be accepted as being of like significance; while the numerous instances from the Great Mound at the Rouge River, if not equally positive, present at least a negative testimony which must be accepted as strengthening the position we have taken.

Of the "five subsequent interments" in the Devil River Mound, I have seen none of the relics, with the exception of a frontal bone, the greater part of which remains in a fair state of preservation. It contains about one-half of the perforation which had been made on the skull of the deceased, which mark had evidently been placed at the vertex of the head and at the junction of the coronal and sagittal sutures. Like the perforation of the other and more ancient skull from the same mound, it is of elliptical form, the greater diameter, 0.87 of an inch, being also at right angles to the length of the cranium. This frontal presents the following dimensions: Length, 4.9 inches; Breadth, 4.9 inches; Least breadth, 3.9 inches. The superciliary ridges are unusually heavy and prominent, while of the portions of the orbits which remain, the upper border of each is of the thick and rounded character pertaining to the savage races. Over the right orbit are indications that a severe wound had been at some time received at that part; but the appearance of the bone proves that the individual must have survived this injury for a considerable period.

There can be no doubt as to the antiquity of the mound at Devil River; and the work with its included human remains must be regarded as being among some of the most unequivocal as well as interesting relics of the mound-builders which have been spared for modern investigation.

I shall proceed by making brief mention of another perforated cranium lately exhumed by Mr. Ludlow from the Great Mound at the Rouge River, Michigan (the locality of my former discoveries), and presented by him to Mr. Hubbard, of Detroit.

In this last skull the perforation, like that of all the other crania from the same mound, is much smaller than that of the skulls from Lake Huron (Sâble River mound, and Devil River mound). It is of an irregular circular form, the diameter at the surface measuring 0.44 inch. The skull is remarkable for the great protuberance of the occipital, which doubtless mainly contributes to its length. Its cephalic index is .722, thus placing it in the dolichocephalic range. The other dimensions, etc., given in inches and decimals of an inch, are as follows: Circumference, 20.10; Length, 7.20; Breadth, 5.20; Height, 5.00; Breadth of frontal, 4.15; Altitudinal index, .694; Index of Foramen magnum, .486; Frontal arch, 11.30; Parietal arch, 12.25; Occipital arch, 10.40; Longitudinal arch, 13.70; Length of Frontal, 4.55; Length of Parietal, 4.85; Length

of Occipital, 4.28; Zygomatic diameter, 5.10. As in the case of a number of other crania from the same mound, though unquestionably adult, the sutures remain unclosed, a point on which, perhaps, more stress should be laid in connection with the many other characters betokening degraded affinities which in former papers I have pointed out as pertaining to the remains of ancient man exhumed from this mound, and from the Great Circular tumulus, in its near vicinity, on the Detroit River.

It will be perceived that in my remarks on the significance of this custom of perforating the head after death, though believing that I have satisfactorily established the point that in the act there was no disrespect intended to the deceased, I make no attempt to define what the more immediate object of that act may have been. My later investigations have added nothing new in this direction, and I must be content to refer to my paper in the Smithsonian Report for 1875, for the views I entertain on the subject. I can only repeat that the constant position of the perforation would seemingly imply some constant object sought for—possibly the suspension of the head.

It may be expected that in this connection I should have something to offer with reference to the prehistoric or neolithic trepanning lately brought to notice in France. I have received, under date of July 12, 1876, a communication from M. Broca, of Paris, from which I make a translation of the following extract, showing conclusively that he coincides with my opinion, long previously expressed, as to the Neolithic trepanning having no connection with the cranial perforation observed by me in Michigan. He says: "I have not yet been able to procure your memoir of 1875, of the 'Detroit Meeting,' and I understand that the Smithsonian Report for 1875 has not yet been published; I only know your researches on the perforated crania of Michigan, by the notice which you have given in the number for August, 1875, of the 'American Naturalist;' but that is sufficient to demonstrate to me that there is no connection between our prehistoric trepannings and perforations and those which you have observed in the ancient crania in Michigan." The distinguished savant concludes with reiterating this belief, in the following words: "You perceive that our prehistoric trepanning differs from yours by a great number of points which I here review." And then follows a running comparison of the two sorts of perforations, from which, with a slight remodel-

ling, a supplementary point or two, and a correction of no primary importance, which I have taken the liberty of making, I give the following:—

Of the Neolithic perforations of France.

1. Some are surgical, others were made after death.

2. Both sexes, and all ages, including infants and children, were subjects.

3. They are from three to five centimeters in length on the head of adults, with very oblique and cicatrized edges.

4. The position is variable.

5. The posthumous were made by the aid of an instrument moved like a saw, detaching the fragments, etc.

6. Object of the posthumous: to secure the fragments, which were used for amulets.

Of the perforations in the ancient crania of Michigan.

1. All were made after death.

2. They are confined to adult subjects and, probably, the male sex.

3. They are from about one to two centimeters in diameter, with oblique but not cicatrized edges.

4. The position is constant — centrally placed at the top of the head, and always on the sagittal suture, or at its junction with the coronal suture.

5. They were made probably with an instrument turning principally semi-circularly.

6. Object unknown (perhaps the extraction of the brain, perhaps the suspension of the head).

And here, for the present, I take leave of this interesting subject, preferring to await what further researches may disclose, through the discovery of additional material, to speculating with what I consider insufficient basis for deduction.

HABITS OF THE MOQUI TRIBE. By E. A. BARBER, of Westchester, Penn.

A peculiarity of the sedentary, housebuilding or Pueblo tribes of Arizona and New Mexico (especially of the Moquis) is the employment of urinals in their households, to a considerable extent. This custom prevails among all classes and ages. The babe of a few months' existence is furnished with a diminutive clay vessel, two or three inches in diameter, and generally made without handles, while the adults use large open bowl-shaped receptacles, which sometimes have a capacity for holding several gallons. These latter are usually placed on the roof-tops of the stone dwellings and the liquid contents left to putrefy in the sun, for weeks or even months. This substance is employed in several operations by the natives (dyeing is probably one) but our stay among them was too brief to permit us to investigate the subject.

THE FORMER AND PRESENT NUMBER OF OUR INDIANS. By GARRICK MALLERY, U. S. Army[1], Washington, D. C.

THE traveller Catlin announced in his well known Letters dated 1839, "the Indians of North America were sixteen millions;" De Tocqueville remarked of the American tribes "there is no instance on record of so rapid a destruction;" and Mr. Hubert H. Bancroft in his "Native Races," after philosophizing that "the intercourse of civilized with savage people results in the disappearance of civilization, or the extinction of the barbaric race," bewails "all the millions of native Americans who have perished under the withering influence of European civilization."

These quotations are but examples of the common belief:—1st, That the native population on the arrival of the first colonists was very large; 2d, That it is now rapidly becoming extinct; and

[1] Brevet, Lieut. Col., Capt. 1st Infantry, detailed with the U. S. Geographical and Geological Survey of the Rocky Mountain Region.

3d, That the cause of that extinction is an innate characteristic or defect of the race, rendering impossible its civilization or even existence with civilized environments. If these correlated propositions are incorrect, it is important so to understand, both for ethnologic theories and practical national duty.

Any present attempt to ascertain by means of the literature on the subject, the Indian numbers in pre-Columbian or even early historic times, within the present area of the United States, must be through a maze of contradiction and confusion. Although the examination should be confined to authorities who did not twaddle about imaginary millions and at least pretended to furnish statistics, even those are only valuable for comparison, and when corroborated by the tests of probability and possibility applied of late years by science to all historiographers.

In 1764 Col. Henry Bouquet, commanding the British frontier forces, officially estimated the number of Indians belonging to all the tribes with whom the whites had then come into contact, as 56,500 warriors, and adopted the proportion of five Indians to each warrior, his total, therefore, being, 282,500. In 1778 Thomas Hutchins, Surveyor General of the British Colonies, gave their strength in the Northern Districts of America, including our thirteen Colonies, at 129,150. A Report to the Continental Congress at the beginning of the Revolution made the number of Indians to be encountered 60,000, and Schoolcraft in his census under the Act of Congress of 1847 enumerated all of them within the United States with a grand total of 383,229, "besides twenty-five to thirty-five thousand within the area of boundaries yet unexplored."

A contrast of the statements concerning particular tribes has more amusing interest than substantial value. Baron de la Hontan in the latter part of the seventeenth century fixed the force of the Iroquois, against whom he served, at 70,000, while the French missionaries about the same time report only 11,100. Adair, who lived among the Southern tribes from 1735 to 1775, says that about 1762 the Cherokees had 2,300 warriors or about 11,500 souls. Stevens, the historian of Georgia, rates them at 3,000 warriors or 15,000 souls in 1774. S. G. Drake gave in 1721, 6000 warriors or 30,000 souls.

In 1834 the Committee on Indian affairs of the House of Representatives reported the Seminoles at 5,000. In the ensuing year

President Jackson estimated their warriors at four hundred (2,000 souls), and the Secretary of War at seven hundred (3,500 souls). According to Sprague the tribe numbered, in 1822, 3,899. For seven years they defied the whole power of the United States, nearly every regular regiment being engaged against them, besides marines and sailors, and for longer or shorter periods altogether 50,000 militia and volunteers. As they cost the government in this war $30,000,000 according to careful recently published official estimates, and over 3,000 lives, it became desirable to increase their apparent force, so it was declared in a Congressional debate, on the authority of a general officer, that 2,000 Seminole warriors had been slain, which at the usual computation would not make their numbers 10,000, if all their warriors had been thus disposed of, which certainly was not true. The probability is that at the commencement of the contest, in 1835, they were not more than 1,500, the proportion of fighting men to the rest of the tribe being greater than that usually found, so that General Jackson's 400 warriors would not indicate 2,000 people. It may be noted in passing, that the Indian Report for 1876 accounts for 2,553 in the Indian Territory, while 475 live in the Everglades of Florida, and others are known to have emigrated to the Rio Grande in Mexico. Those on Reservations were less than 2,000 at the close of the late rebellion in which they suffered severely. With all the losses of two wars, those remaining in the United States have in forty years more than doubled in numbers.

Bartram, about 1775, estimated the Creeks at 100,000, Adair at the same date at 17,500, and Drake in 1785 at 17,000. The Committee of the House of Representatives, in 1834, reported 22,000. Father Rasle, early in the seventeenth century, wrote that he had seen in one place in Illinois 1,200 fires kindled for more than 2,000 families, but other missionaries in the same region, not much later, describe their trouble in finding any Indians at all. This statement of the good father is not necessarily to be classed with some other travellers' tales; but, as contrasted with the fruitless searches of his brethren, affords a good illustration of the causes of honest exaggerations. He may have met a great hunting expedition, perhaps a tribe in the act of migration, which lit a large number of fires; but its transient encampment no more indicated the population of the district, than would the halt of a great caravan establish the population of the Sahara.

The commissioners to treat with the Sioux for the relinquishment of the Black Hills, in June, 1875, tried their hands in working upon old statistics, and recited the estimate of that body of Indians by the Secretary of War, in 1829, as 15,000, by another authority in Niles' Register of the same year, as 40,000, and by another Secretary of War in 1836, as 23,000; winding up with a plaintive comment that "the data from all these sources are probably erroneous," with which wise conclusion any investigator of the subject will readily agree.

The most discriminating general view yet presented, the influence of which upon the present paper is gratefully acknowledged, has been by the historian Bancroft, who suggests 180,000 souls as the maximum of the native population, east of the Mississippi, and south of the St. Lawrence and the chain of Great Lakes, in the early part of the seventeenth century. This opinion is entitled to great respect, as it is known that the careful author devoted much research to the subject, with the intention of presenting a more extended discussion than appears condensed in Chapter XXII of the third volume (published in 1840) of his history; but its value is somewhat lessened by the consideration that the only reliable classification, viz., by the linguistic families, languages and dialects, was not available at the time of his investigation, indeed is only now beginning to be understood. From this fact and the confused synonymy hereafter more fully explained, raising a suspicion that minor divisions have been counted more than once, it is difficult to compare his figures with the state of the tribes as now known; but carefully enumerating only the bodies of Indians clearly included by him, there are found to be 117,700 of their descendants still remaining in the United States and beyond the Canadian border, though by no means all now within the territorial limits mentioned by Mr. Bancroft—the Iroquois and Chippewas or Ojibwas being the only considerable bodies at or very near their pre-colonial habitat. This number would certainly be increased by a critical analysis of the present official Indian population, and by including the considerable portion of the descendants of eastern tribes now mingled with the whites, and avowedly counted with the latter in the census. Without such nicety, however, and simply referring to the last Census Report, and those of the Indian Bureaus of the United States and the Dominion of Canada, there appear in known localities and with recognizable identity, over sixty-five per cent. of

the same Indian stock found at the early settlement of the country east of the Mississippi, according to Mr. Bancroft's estimate. Admitting the latter as approximately correct—and from considerations to be presented, it does not seem to err in illiberality of allowance—the decrease in nearly three centuries is neither so rapid nor so frightful as to authorize the common coronach of poets and sensational essayists.

The report of the Commissioner of Indian Affairs for 1876 sums up 266,151 Indians in the United States, apart from Alaska. The Census of 1870 reports as Indians out of tribal relations, 21,228, which at first might seem to be an absolute addition to those in the Commissioner's tables, as the latter do not make any allusion to Indians known to dwell in a number of the States, for instance, the 1,000 Passamaquoddies and Penobscots of Maine; but in other cases there is a probable inclusion of bodies not on Reservations or connected with Agencies, whom the census returns also appear to embrace. Making all due allowances, there are at least 5,000 more in the United States than as enumerated by the Commissioner, which would give a total of 271,151, excepting those in Alaska. This exception introduces an instructive lesson, as the Superintendent of the Census supplies the omission of the Alaskan population by an estimate of 70,000; whereas Capt. W. H. Dall, of the U. S. Coast Survey, in volume I of the "Contributions to North American Ethnology" of the U. S. Geographical and Geological Survey of the Rocky Mountain Region, lately issued, furnishes an exhaustive summation of the same people, at substantially the same time, as 25,704; thus teaching that the most careful mere estimate on this subject, even in our day, always vastly exceeds the truth obtained by the personal examination of competent explorers. If such a change in the reported numbers had been made after the Alaskans had been under an Agency, it would have been attributed, either to fraud in the first enumeration for the purpose of swelling the ration return, or to the fated sudden mortality of all tribes connected with whites, whereas, in fact, such discrepancies, used as conclusive arguments for the latter theory, are often but the result of accurate information succeeding vague guesses.

In comparing the authorities, it is obvious that the lower estimates are made by writers whose judgment and veracity in other matters are admitted, such as Sir William Johnson and George

Bancroft, while the high figures are given by a Baron de la Hontan, whose adventures rival those of his brother Baron, Munchausen, and a Catlin, whose imagination discovered a great river, tunnelling the Rocky Mountains. The history of Smith not only tells of the numberless followers of *King* Powhatan (nothing at all resembling monarchy being known to any of his, the Algonkin family) but describes pearl, coral and metallic copper, as part of Virginia's wealth, and states that its crops of corn were successively planted and gathered three times in five months, an arrangement of the harvesting seasons not now perceived. De la Vega, an historian of De Soto's expedition, saw during his long route great towns frequently in sight of each other, a report wholly inconsistent with the known resources of the region to its native inhabitants, but quite worthy of a traveller whose detailed courses and distances reached a point probably somewhere on the lower Mississippi, but mathematically at the same time 600 miles north of Lake Superior.

It is also noticeable that while the figures of later writers, applicable to the same bodies, have been far less than those of their predecessors by some short periods, during which no marked change was known to have occurred, yet the whole world believed the later, without discrediting the earlier, and accounted for the diminution by rhapsodies about decadence, and a profound theory manufactured to suit false premises, that what they called the red race was *ferœ naturæ*, and could never be tamed nor exist near civilization. This has not been wholly an error of honest ignorance, but of wilful determination; not only the early colonists but the later backwoodsmen persuading themselves, to reconcile their consciences and interest, that the Indian was of inferior and brute race. So large a part of mankind has participated in, or benefited by, the crimes committed on this theory, as to receive it and all statements supporting it with eagerness.

Having sufficiently examined the estimates of historians and travellers, and no hope existing of any accurate statistics from the recordless tribes themselves, it becomes necessary to inquire into the probabilities arising from their migrations, traditions and habits so far as ascertained by the latest research.

The view now held by some distinguished Ethnologists, founded on many considerations, is that the main source of distribution of our Indians was the country drained by the Columbia and Fraser Rivers, though how and when they arrived there is by no

means agreed upon. That region, where very numerous mortuary vestiges indicate the former presence of multitudes, though possibly *in transitu*, was, and remains, admirably adapted to their subsistence. In addition to the marvellous salmon and trout fisheries, there were bread roots in profusion and much large game, such as bear, deer and mountain sheep. If the successive waves of continental migration did originate on the Pacific Coast, it is scarcely to be supposed that they crossed the arid plains only lately explored by us or even the more eastern prairies, where with all then-existing facilities the support of life would have been most difficult. The savages relied at first mainly on fish, secondarily and later on the chase, and only in their last stages of development on agriculture, which, though a greater resource among some tribes than is generally understood, became so after their long continued occupancy of regions near the Atlantic and the great lakes. They could neither, before obtaining the horse, then for ages extinct on this continent, pursue to great advantage the large game of the lower prairie, necessary for their subsistence while passing it, nor transport stores before collected, and moved probably (as one route, others being also contended for) *via* the head waters of the Mississippi, and the outlet of Lake Superior, resting on long lines and with little lateral spread, near rivers, lakes and the ocean. Even on those selected routes, they left behind them immense tracts, sometimes as not suited to their fancy, or for farther separation from their old homes, perhaps forcedly abandoned, as expansion of the race seems generally to have been occasioned by stronger tribes driving off the feebler, as in the Eastern Hemisphere. The greater part of the districts east of the Rocky Mountains and some to their west, where the Indians are now, or in recent years have been found, and much of which was vaguely charted in our juvenile atlases as the "Great American Desert," was, in fact a solitude when America was discovered, the population being then confined to the wooded borders of the traversing streams. For example, the Dakota-Sioux, now classed with no great accuracy as nomads of the prairie, were, when first known, lake and river Indians, being found by Allouez in 1666 west of Lake Superior; and their recently discovered picture-calendar shows that at least some of their divisions had never lassoed wild horses before 1812, though they had become acquainted with that animal through more southern tribes, a few years earlier. The Pawnees also, and their

congeners, historically known as habitating the head-waters of the Arkansas, were, only after they became possessed of horses, roamers of the plains and absolutely dependent as now upon the buffalo for food, shelter, fuel, clothing and barter. The vast expanse commencing on each side of the Ohio River, and at no great distance from it, covering half the space between the great lakes and the gulf, was fairly stocked with game but not sufficiently with food fishes—Mississippi's turbid stream excluding the ocean wanderers — and was therefore not adopted as the permanent abode, at least one continuing three centuries ago, of any considerable population. Marquette, voyaging in 1673 from the Fox River to the Wisconsin and down the Mississippi, found no trace of man until he reached the confluence of the Des Moines. In 1679 La Salle, exploring from the head of Lake Michigan to the southwest, only met Indians after a month's travel, who were a band of the Illinois at the present site of Peoria, and their tribe had not long before retired from the east. Vermont and western Massachusetts and much of New Hampshire were left unoccupied. On early maps the low country from the Mobile River to Florida was marked vacant — the Seminoles not appearing in the latter region until after it had become a dependency of Spain — and the oldest reports from Georgia assert with gratulation that there were scarcely any savages within 400 miles of Savannah.

It is erroneous, when considering the distribution of our Indians, to regard them generally as nomads, though some of them were in a stage of migration, as once were the Gauls and Goths, in search of better homes. Nearly all of the tribes had obtained, or at least claimed and sought to retain, separate districts in which they had permanent villages, often stockaded, and sometimes containing communal houses for the continuous use of several families. From these villages they sent forth hunting and war parties, which, during their long absences, used the more temporary shelters to which some writers have limited the race. Without referring to the lasting structures of the Pueblos, from the roomy and carefully bark-built Ga-nó-sote of the Iroquois, to the Winnebago thatched houses of matted reeds, the strong palisadoed structures of the Arickaras, the planked and loop-holed buildings of the Chinooks, and the dome-shaped, earth-covered lodges characteristic of California, the Indians had homes not much less solid or comfortable

than were common in Europe within its earliest historic period, and they abandoned them as did the Old World migrants, only from pressure or other necessity.

What may have been a reflux tide, or simply the flow of expansion, after the Atlantic shores had been reached and occupied so as to cause collision even among scanty numbers with such restricted resources of subsistence, commenced (before the advent of the whites, though afterwards stimulated by it) from intestine wars between the tribes themselves and shows the great tracts before left vacant in the interior.

The terrific prowess of the Five Nations had by 1660 driven many tribes of the Algonkins and the remnant of the Hurons in wild flight to the distant bays of Lakes Superior and Michigan, so that the Jesuit missionaries in that year found not a single resident Indian on the shores of Lake Huron or any of its islands, and the whole peninsula of Upper Canada with lower Michigan was a wilderness. So also the Shawnees, repulsed from the southern shores of Lake Erie in pre-Columbian days, and first known to the whites on the Savannah River, seemed to experiment for two centuries in choosing a permanent home, appearing successively in the south-west part of the Ohio Valley and in Pennsylvania, next on the Scioto and Miami, having also rested for some time in the vacant highlands of the Carolinas. In 1742 when the Iroquois, at Quaker instigation, rebuked their *Lenni Lenape* subjects for complaining about Broadbrim's construction of the celebrated "walking purchase," they ordered them to the alternative choice of two fair valleys less than a hundred miles west of the Delaware, proving that at even so late a date there was still plenty of room on the Susquehanna and Shamokin, which we might suppose would have long before been seized as an Indian paradise. It was as easy and judicious for the discontented eastern aboriginal to "go west" in the seventeenth century, as it was for Mr. Greeley's "yonng man" in our time. This occidental emigration became still more convenient to him when the iron, gunpowder and horses, brought by the whites, revolutionized his pristine habits and bestowed dominion over nature in the plains where before his rude arts could not suffice, affording another instance of a want supplied, in the grand economy that overrules mankind, through the very cause which made it requisite. The same civilization that pressed

the Indian race from its chosen water courses, provided the facilities for its enjoyment of land which without them was uninhabitable.

All these facts grouped together teach us how insignificant was the territory actually occupied by the natives before the Indo-European race could possibly have affected their numbers or distribution, and how silly are any estimates obviously influenced by a calculation of the product of their number on some one square mile, multiplied by the figures expressing all the square miles embraced between the Atlantic and Pacific and certain degrees of latitude.

It is true that the linguistic theory does not admit the necessity for any migrations from the western coast, such as have been suggested and above indicated, or that there was any American *officina gentium* such as was once agreed upon for the old world. The mounds of the Mississippi valley prove that at some time it held a large population. Whether that population, though of long endurance, suddenly disappeared by southern immigration or otherwise, whether the mound-builders were the direct ancestors of the Indians our forefathers met, and whether their remains prove with any certainty great contemporary numbers instead of great antiquity, are questions yet *sub judice* and need not be now discussed. It is, however, conceded that the people we, in our ignorance, term "mound-builders" were agricultural, had several arts unknown to the historic tribes, and had passed away before the latter had come within our knowledge. The general and frequent collection through all our land of objects of native manufacture, such as imperishable arrowheads, is not necessarily a proof of either continuous or occasional multitude in their makers, an alternative being that the wars and hunts of a small number of people for many years would leave the same traces. Linguistic researches show so many distinct stocks that no system of migrations from or beyond the Pacific hitherto set forth would account for all of them, and the negative evidence, for what has been styled, in imitation of Athenian assumption, the autochthonic theory, receives some support from recent geologic discoveries. The ethnologists and philologists, though so widely disagreeing in other respects, both admit that the actual distribution of the natives at the time of, and shortly after, their discovery was as above presented, and the immediate practical inquiry concerns the tribes then and still

known to us, rather than ancient inhabitants, whether or not the ancestors of those tribes.

This distribution rendered misconception of their numbers by the early white visitors almost unavoidable. The latter, using the natural and only readily available highways of ocean and river, met the Indians precisely where they were most numerous and stationary, and could not thoroughly explore the endless tracts where they only occasionally roamed or which they entirely avoided, while the enormous distances of separation prevented any one traveller from actually seeing, and thereby distinguishing between, but a limited number of tribes. Even if an expedition through the wilderness were risked, the very presence of the explorers, from obvious motives of curiosity, barter or defence, attracted all the bands scattered over many miles. A tradition of our navy, revealed by one of its officers, illustrates the perils of statistic-gathering under similar difficulties. Years ago a frigate touched, for the convenience of watering or the like, at a south sea island, then little known, and an ambitious Lieutenant carefully counted the people of a village near by, after which the ship found it necessary to pass around to the farther side of the island, where was another village of which he also took a census, and obtained information of several other places in the interior, of equal size, so by a little addition and multiplication a good account of the inhabitants was presented, but was somewhat invalidated by the later discovery that not only had all the people of the first village been counted with those of the second, but that every man, woman and child on the island, attracted by the vessel, had crowded to each of its landing places.

Apart from such innocent blunders, cunning and vanity would induce every tribe to exaggerate its own importance, which there was at first no evidence to contradict. So late as 1829 Naw-kaw, a Winnebago Chief, attending a balloon ascension in the Battery in New York, where there was an immense crowd, and being asked if he had ever seen so many people together, replied haughtily, "we have more in our smallest villages." Considering that his whole tribe only mustered then about 3000 souls, this may pass as a creditable specimen of aboriginal brag, which, if government officials had not already become familiar through systematic fraud with the actual count of the Winnebagos, would doubtless have been adopted as a faithful comparison to influence statistics, as

has actually occurred when other chiefs, likening their few score warriors to "the leaves of the forest," have been seriously quoted. The early travellers received such tales with alacrity, to enhance their own adventures, repeating them with the fabled reproductiveness of the three black crows, even when they did not wittingly imitate Falstaff in the multiplication of his men in buckram. When hostilities commenced, on the one hand the soldiers of fortune and pioneers who were engaged, overstated the number, power and resources of the enemy, to swell their own services and claims, while the home-abiding, kept in constant fright, added legions to the small war parties whose activity rendered them almost ubiquitous in ravaging extensive settlements. These bands seldom exceeded forty, and were more commonly of but six or seven warriors, their tactics being surprise and intimidation with the adoption of many devices to increase their apparent force. The great conspiracy of Pontiac, embracing nearly all the tribes east of the Mississippi, after years of preparation only brought to the main body at Detroit in 1763, a strength estimated at the time from 600 to 2000 warriors, probably near the lower number; but they were quite enough to fill all the colonies with dismay. When the deceptions of the wily chiefs could successfully coöperate with the vanity and ignorance of the historian, whose tales were greedily swallowed by the frightened settler, there need be no wonder at the exaggerations handed down to us by our grandfathers as household words, to impugn which, now seems little short of profanation.

A potent cause of error in the enumeration of our Indians, extending even to modern times, and from which we are scarcely yet free, necessarily arose from their utterly confused synonymy. Besides the name by which each tribe called itself, its several neighbors on all sides gave it one wholly different, and as met by the Spanish, French, and English, a new title was either independently coined, or one of those first encountered adopted or translated, with ever varying pronunciation and orthography, so as soon to defy the recognition of etymologists. McKenney and Hall, in their "History of the Indian tribes of North America," published in 1855, present 272 names given as of different tribes in the early narratives and histories, while confessing themselves at a loss to ascertain upon what people many of the appellations were bestowed, and suggesting the probability of duplicates, which

impression a cursory glance at the list by any one instructed in the more recent linguistic researches, will convert into certainty.[2] Thus both in literature and tradition the list of the very sociological bodies or organizations of the Indians was erroneously lengthened, and the supposed strength of each real tribe counted perhaps several times. So also when, in the later classifications, names before used were dropped or changed, there seemed cases of absolute extinction. Perhaps it may be generally known that Wyandot is the present title of the old Hurons; but not many readers of Cooper are aware that some of the Mohegans he annihilated survive as Munsees, Brothertons, and Stockbridges, though as their eastern enemies the Narragansetts and Niantics called them Pequottoog (abbreviated into Pequod by the Connecticut settlers) they suffered, in historical confusion, a still earlier extermination under that appellation. When tribes were no longer seen on their ancient grounds, their obituary was pronounced, and if met again in distant regions, perhaps with new habits of life and unfamiliar titles, they were only noticed to swell some romantic estimate of the old population, their present numbers being for

[2] Some examples may be of interest, though not confined to the list mentioned.—The Mohawks were called by various writers—Anies, Agniers, Agnierrhonons, Sankhicans, Canungas, Mauguawogs, Makwaes and Ganeagaonhoh. The Oneidas also appear as Oneotas, Onoyats, Anoyints, Onncionts, O-na-yoté-kä-o-no and Onoiochrhonons, and the Senecas as Sinnikes, Chennéssies, Genessees, Chenandoanes, Tsonnontouans, Jenontowanos and Nundawaronoh; while the leagued people to which they all belonged, properly named Ho-dé-no-sau-nee, was termed Iroquois by the French, and Mingos or Mengwees by the English. The confederacy calling itself Dakota was stigmatized by the neighboring Algonkins as Nadowessi. "hated foe," from, as generally conceded, a root meaning a venomous serpent, and the French gave it their plural —Nadowessioux, whence by elision, Sioux. Dr. H. C. Yarrow, U. S. A., has, however, suggested that the French designation "Indiens du Nord-ouest," is the true origin of the title Nadowessi or Nadou-essi. The early English writers used their own plural—Nadowessies. The French missionaries also called the Titons—a grand division of the Sioux tribes, and who were the first of them to seek the prairie—by the title Poualac, as of no connection with the Dakotas, and with several variations in spelling. The nation was also called by the Iroquois, Wä·sä'-seh-o-no; by the Poncas, Bwa[n]; by the Arapahos, Natenéhima; the Cheyennes, O ò'homò·yo; the Crows, Barashupgio and the Arikaras, Sunnúnnat. The Comanches, as the Spanish in Mexico styled the tribe, call themselves Na-uni, but were known to the Caddoes as Sowato, to the Osages as Partooku, and to the Wacoes as Naratah. The old French name was Ietans or Hietans, and our early settlers spoke of them as Paducas—these different epithets showing no mere literal discrepancy or variety in pronunciation, but absolute difference of root. The word Paduca recalls one of the few instances in which the narrative of Lewis and Clarke betrays sentimentality, where, after the "Great Padouca Nation" is spoken of as once occupying the country between the upper Platte and the Kansas, the text seems to lament that "of the Padoucas there does not now (1804) exist even the name." True enough, that *name*, bestowed with little reason, became disused, but the *people* still exist as Kiowas or Comanches, or both.

that purpose multiplied by the ratio of supposed general decadence adopted partly on the false report of their own extinction.

Instances of combination and absorption, now well ascertained, have swelled the wail of extirpation. The Mascoutins, long considered an extinct tribe, early charted as south of the Outagami or Fox River, were merely some bands, under a local name, of Saukees and Kickapoos, which name naturally disappeared with change of habitat. The Natchez (a most interesting though never very populous body), once supposed to have been entirely destroyed by the French, at about 1730, are to-day keeping up their national organization in the Indian Territory, though for sometime lost among the Creeks. The Hitchiti have been rediscovered among others of the Muskoki family, and a remnant of the Tutelos, frequently identified with the Meherrin of Virginia, among the Canadians at Brandfort, after historic doubts had been started whether any tribe so named had ever existed. A fair example of combination is presented by the so-called Uintas, now at the Agency of that name. They are composed of Utahs from the region of Utah Lake; Suivirits, from the Castle Valley Country; Weber Utes from the Weber River; the greater part of the Yampas; some of the Pah-Vants from Central Utah: and Uinta Indians proper. These bands are all noticed together in the last Report, as numbering 650, and have each been, not long since, and without any important change in their strength, separately numbered at about the figures now given for the whole, thus in quite recent times improperly adding to the general census; and now by their subtraction assisting the theory of rapid decrease. Consolidation has been noticed on a larger scale west of the Rocky Mountains and adoption has been so notoriously frequent even among hereditary enemies, as to induce a suspicion that the disappearance of the names as well as numbers of some of the North-eastern Tribes has been occasioned by their taking refuge among their kinsmen of the same Algonkin family, the Chippewas, called also Ojibwas and Mississaugas, into whose large population, now over 28,000 in the United States and Canada, they may readily have been absorbed.

The main explanations of the lately unquestioned law dooming all our native race to speedy death, have been in their constant wars and the strange diseases introduced. As regards the latter, small-pox has been the most fatal and its ravages among the

Pawtuckets, Pokanokets, Massachusetts and many other eastern tribes recorded, besides those on the Pacific Coast, where it was conveyed through inter-tribal channels to districts still uninvaded by the whites. It should be remembered that this epidemic has raged among other races and in other lands in much the same manner, depopulating some localities for a time only, and a lesson as to the extravagance of estimated tables of mortality at occasions of pestilential excitement may be learned from the Report of the Minister of the Interior of the Dominion of Canada for 1876.

An awesome story had been circulated in the newspapers and called to the attention of government, that in 1868 the Indians of Vancouver's Island had been nearly exterminated by the small-pox, the habitual phrase "hundreds of bodies left unburied" at designated points, being reproduced. As officials had been accused of neglect, a full inquisition was ordered which established the truth that only eighty-eight Indians had died from that disease in the whole district during the entire year, and that the fright of those who fled and told their piteous tale to the nearest settlers, who exhibited no disposition to verify it by a visit to the infected region, had occasioned the widely credited rumor, which without this prompt investigation, would soon have grown into an authentic tradition, and been quoted to prove the extinction of a great tribe. The sweeping and always intangible plea of epidemic disease has often been resorted to for the rehabilitation of travellers arraigned for a too lively imagination. Rev. Samuel Parker, in 1836, reported the Kalapuyas of Oregon as 8000 souls, but Rev. G. Hines who lived among them for years beginning with 1840 found only 600. Similar glowing accounts of the vast field for missions in that region led to the detail thither of a disproportionate force of missionaries, and when the numerical discrepancies were discovered the blame was cast upon the ague-fever of 1829 and the still earlier small-pox, though the main destruction by both diseases had occurred long before any of the misleading agents were on the ground, and not in the interval between that time and their detection. The fact is that many Indians have died of small-pox as did many Europeans before the days of Lady Mary Wortley Montagu and Dr. Jenner, and also, that those who could ran away from the danger, as more enlightened people do now, with the difference that the latter are brought back by the ties of real and personal property, which not troubling the former, they ever after avoided a locality that in their

theory of disease was the scene of demoniac wrath. It may be noted that this particular disease has ceased to be a scourge to the tribes, the reports of fifty-six Agents in the years 1874, 1875 and 1876, not including any fatal case.

The destructive element of war did not begin its influence during our history, but was the normal condition of all tribes found in our territory, and we only added to the list of combatants. Every native nation was in a state of war with every other not in actual alliance which was seldom lasting. The Algonkin divisions often fought, each with the other and all with the Iroquois and Dakotas whenever they met, while the scions of the latter stock, Sioux, Mandans, Assiniboins, Crows, Minnetarees, etc., etc., waged constant internecine conflict. That the whites did not introduce wars of extermination and dispossession is well shown in the history of the Iroquois, who, according to their traditions once resided near Montreal in subjection to the Adirondacks, against whom they rose unsuccessfully, and to escape destruction fled up the St. Lawrence to the Ontario and entered the present state of New York. When, chiefly through the excellence of their governmental system, strength was gained, they turned their arms against their old masters, long before the French occupation, persisting in continuous revengeful attacks until in 1535 the Adirondacks had been driven wholly out of their former country and beyond Quebec. They also virtually exterminated the Eries and Andastes, their linguistic kinsmen, and carried conquest in all directions. In 1607 Capt. John Smith met them in canoes navigating the upper Chesapeake to attack the Powhatan confederacy. The Dutch trading with them in 1615 at the present site of Albany, the early possession of fire arms thus obtained only stimulated their preconceived design of universal dominion, in which they sent forth bands who were welcomed back with victorious scalps taken in forays from New England to the Mississippi, and from the northern limits of the Great Lakes to the Tennessee and the Carolinas.

The whites were never more systematic or successful in subjugation by force of arms than were several of the Indian leagues, and all we know of the prevailing customs of the continent tells us that war was with its natives a necessity for the assertion of manhood, if not inculcated as a religious duty. It was the great highway to distinction, hunting being the mere business of life, expertness in which only conferred respectability and competence

(as did trading not so many years ago, when Europe was in the militant stage) even oratory, so highly admired, seldom maintaining influence when divorced from courage and success in arms. The worship of Janus might have been introduced with special convenience, as no doors would have been needed for his cis-Atlantic temple, but in lieu of his professed adoration, the air of America never ceased to vibrate with the war song. Perhaps, since the power of the white race has been established with restraining effect, there have been fewer and less bloody wars than were frequent for centuries before, and certainly for years past no whole tribe, and but a minority of individuals among very few of the tribes into which the 300,000 living Indians are divided, have been on the war path against any other in the United States. No such conversion from less to greater combativeness is, therefore, apparent as would account for any important change in the Indian population. If warfare has been a chief cause of their decrease, they were on the wane long prior to their discovery. Of this, however, there is no evidence, though doubtless the consequences of militancy prevented any rapid increase, and conquerors like the Iroquois spent their own blood, as did their Roman prototypes, with the same plan of recuperation by adopting subjects into their body politic, and of enjoying central peace while exercising their plangent prowess beyond an ever-growing frontier.

It will be useful to examine the facts concerning a *representative* body of Indians, which should be one early and familiarly known, and which shared all the changes brought by the European settlement. For this purpose, the Iroquois, first called the "Five," and afterward the "Six Nations," will be admitted as a perfect selection. They were among the first of the natives met by, and were familiar alike to, the French, Dutch and English. Besides the conflicts already noticed, they fought fiercely with the French during the whole period the latter held Canada; and most of them siding with the British, took an active part in our Revolutionary war, with the result of being dispossessed of their lands, many driven into Canadian exile, their admirable league destroyed and very tribal organization seriously weakened. For two centuries and a half they have been exposed to the diseases and alcohol of civilization, and for much of the last century, in their present homes, have been surrounded with all its good and bad influences.

Dr. Lewis H. Morgan, the distinguished author of the "League

of the Iroquois," places their maximum strength at about the year 1650, at 25,000; but in his "Ancient Society" he modifies that view so far as to admit that there were never more than 25,000 Indians in the state of New York, including with the Iroquois the Algonkins east of the Hudson and on Long Island, and the Eries and Attionandarons or Neutral Nation in the western part of the state. Wentworth Greenhalgh, in 1677, travelled through the Iroquois country with instructions to ascertain their true numbers, which he reported at 2,150 warriors or 10,750 souls. Sir William Johnson in 1763, estimated their strength at 2,330 warriors or 11,650 souls, including the Tuscaroras who had joined the Confederacy as its sixth nation in 1715, and had, therefore, not been mentioned by Greenhalgh. No one will doubt that Sir William Johnson, for many years British Superintendent of Indian affairs, who lived and married among these very tribes, had a more thorough knowledge of them than any other white man at that period had of them or of any other tribes on the Continent. His official report has consequently nearly the weight of a census return.

There were, in 1877, in the United States, of the Six Nations, in ascertained localities and distinct bodies, 6,715 souls,[3] besides some fragments known to be commingled with other tribes, and not easily distinguishable.

The annual report of the Minister of the Interior for the Dominion of Canada, for 1876, tabulates as follows for the Iroquois living on Reservations or connected with Agencies in that country.

In the province of Ontario	Oneidas of the Thames	604
	Mohawks of the Bay of Quinte	822
	Six Nations of Grand River	3,069
In the Province of Quebec.	Iroquois of Caughnawaga	1,511
	Iroquois of St. Regis	947
	The addition being	6,953

Their annual increase during the last eight years has been about

[3] Their distribution was as follows: Senecas, in New York and Pennsylvania, 2,963, in Indian Territory, 235; Eastern Shawnees, 115; Oneidas, in New York, 249, in Wisconsin, 1,324; Onondagas, 493; Cayugas, 184; Tuscaroras, 401; St. Regis, 751. The St. Regis Indians are chiefly descendants of Mohawks, who emigrated to Canada in the seventeenth century, under the guidance of Jesuit missionaries, and were sometimes called Caghnawagas. A portion of them afterwards settled on the St. Lawrence, and the boundary line when established between the United States and Canada left part of them to be now reported in the Canadian, and part in the United States census. The small band now known as "Eastern Shawnees," early united with the Senecas, and have probably lived with them since 1711.

two per cent., and the portions of the same tribes in the United States have also shown of late a regular growth. Combining the numbers on both sides of the border, there are 13,668 this day clearly accounted for at points designated, which we may at least compare with Sir William Johnson's trustworthy figures of 1763, and the result is that there are shown to be more than 2,000 Iroquois now living than there were thirteen years before our Declaration of Independence. This does not corroborate Mr. Schoolcraft's *ex cathedrâ dictum*, that "the red man withers at the touch of civilization."

A criticism may be urged upon these figures, that they include in the case of some of the present Canadian and New York Iroquois, a considerable number who are not of pure blood; but, while that fact may suggest discussion about amalgamation, it does not help the "withering" and "blight" theory. Consul Blake's laborious and impartial investigation in 1870, of the Indians in British America, shows that there is no sterility in the mixed blood, the numbers of the hybrid tribes in Canada having multiplied in steady progression since 1844, and the same fact is noticed in New York and the Indian Territory, as well as in parts of Massachusetts and Wisconsin, where the sons of the soil have left families only known to be theirs through records and tradition, being hardly traceable by name or appearance. When the Dutch of Pennsylvania and the French of Louisiana have begun to anglicize their habits and partially their surnames, becoming intermarried and commingled in the general transactions of life with more aggressive immigrants, we do not speak of their extinction, but of their fortunate absorption into the national unity. In this sense there may well be a disappearance of the American stock in accordance with beneficent law; but that is widely different from its supposed eradication through deplorable fatality. The actual amount of this absorption is not deducible from our last census, as its announced plan was, that when any persons of Indian blood were found residing with the whites, adopting their habits of life and methods of industry, they were classed with the white population. The loss to Indian credit thus resulting may be offset against the admixture of foreign blood in reservations.

Instances are clearly ascertained of other Indian divisions having largely increased during the last century. The French, who seldom erred on the side of minoration, in 1736 estimated the

Dakota-Sioux as 12,000. Captain Carver in 1766 considered them not so numerous. Schoolcraft in 1847 tabulated them as 14,500, besides 6,570 in another column, probably intended to be included, and making their number 21,000. Comparing the Report of the Indian Commissioner for 1876, with that of the corresponding Dominion Bureau of the same year, and the concurrent opinions of officers of the United States Army, published or known to the present writer, the actual strength of the Sioux Confederacy in the United States and Canada cannot be less than 50,000. If the French were right in 1736, this body has quadrupled in 140 years; and if Schoolcraft, whose spectacles in looking at Indian masses were by no means concave, was correct in 1847, it has doubled in twenty-nine years, though at war with other tribes or whites, or both, for nearly the whole period since they were first known, the latter part of which has been with general exposure to foreign diseases and whiskey, though not so generally to the better concomitants of civilization. Without, however, relying upon any comparison of estimates, it is enough to quote the report of the missionaries who have lived continuously for the last half century among the Sioux, that they have increased one-third during that time. The letters of Messrs. Riggs and Williamson lately published, clearly show the rationale and duration of decline attending the first "transplanting," as the latter happily terms the change of condition.

No actual count of the Cherokees was made until 1809, when they were found to number 12,395. In the Report of the Indian Bureau for 1876, they appear as 21,072, notwithstanding their losses in the rebellion. The Seminoles have before been noted as doubling under the same disadvantage during the last forty years, and other examples of similar increase could be accumulated.

It may here be remarked to avoid criticism, that a number of bands of several tribes before discussed, have been accounted for beyond the limits of the United States, for whom so far as an inquiry is confined to the aboriginal population of the latter, proper allowance must be made; but there have been some exchanges with Canada to our credit; for instance, part of the Hurons and several Algonkin tribes, and the main point of interest is not whether displacement has left the descendants of the historically recognized Indians of our country north or south of the frontier, but whether, since being subjected to the influence of

civilization, they have become extinct or lamentably reduced, moribund if not in *articulo mortis*, according to the popular belief.

Any fair examination on the subject must give due weight to cases where loss is known, and in that connection the instance of California should be specially discussed, where, including Oregon as partner in its bad eminence, the destruction of Indians directly caused by the immigration of the whites has probably been greater than in all the other parts of the United States combined. The discovery of gold brought there with a sudden rush, a lawless and greedy host of miners, squatters and adventurers of the worst type, when there was no provision made by law or ruling custom, either for natives or orderly settlers. The tribes there were unusually mild in character, and some of them had been already successfully subjected through the Spanish missionaries to civilized usages. Mr. J. Ross Browne commenced his vivid article in Harper's Magazine for August, 1861, with the assertion that when the state was admitted into the Union (which was in 1850) the number of Indians within its borders was 100,000, and under the heading of California the Report of the Commissioner of Indian Affairs for 1876, enumerates but 8,424. Mr. Browne was extravagant in his estimate, though he was not and could not be so in his denunciation of the murders of Nome Cult Valley and Humboldt Bay, or of the legislative crimes by which the tribes were driven from their old homes to improperly managed reservations, out of which they were speedily cheated or squeezed, leaving them without any resource whatever. He might have detailed also how, when Governor Weller authorized one W. J. Jarboe to organize a company, he in twenty days killed more than 400 harmless natives, took 600 prisoners, and had only one of his own command killed, and three wounded — reporting upon those facts a campaign of fifteen victorious battles — and also how the Round Valley tribe had its 20,000 acres of fine arable land changed for a desolate mountain. Nevertheless, there were not so many Indians massacred and starved as he supposes, simply, and perhaps only, because they did not exist to be in the way of Anglo-Saxon enterprise.

The Secretary of State of California, shortly after its admission, stated the number of its Indian population to be 32,000, in which he was doubtless prompted by the Report of the Spanish missionaries in 1802, giving the same figures; but an analysis of

the latter shows how loosely its total was composed. They tabulated their eighteen missions at 14,391 only, added for mustees and mulattos, 1300, and a rough guess at what they called "wild tribes," as 16,000, thus forming the 32,231 of their report, in which, as would naturally be inferred, and as Fayette Robinson specifically states, they included the whole of the peninsula of California, as well as other lands beyond the present boundaries of the State. In the same paper, the whole population of Alta California is noted for the same year as 15,652, with the annexed expression, "including Indians attached to the soil." Making the deduction for error found to apply in all mere estimates of "wild tribes," not long and familiarly known, the missionary authority would indicate that the Indians of California were not in 1802 much more than 20,000. Our Commissioner's Report is almost equally misleading in the opposite direction, giving only the census of the Agencies actually in the State, and an estimate of those not attached to any Agencies; when there are many Indians in it, officially under Agencies located a short distance beyond its borders, and others who are known to have moved or fled from California within recent years, who undoubtedly are the descendants of tribes embraced in the Missionary Report. A statement of those presented under the excellent authority of Major J. W. Powell, in charge of the U. S. Geog. and Geol. Survey of the Rocky Mt. Region, is as follows:—

Mojave and Chimehueva on Reservations	2,070
Yuma on Reservations	352
Mojave not on Reservations	700
Indians reporting to Pi-Ute Reservation in Nevada .	500
Panamints not in any report	400
Indians who crossed the mountains to Nevada, not at Agencies	500
Those gone to Idaho and Oregon	300
Total number of California Indians not specifically reported as such by the Indian Commissioner . .	4,822
Added to those so reported	8,424
The total comprises	13,246

For comparison with the Missionary Report should be added all the Peninsula tribes, no reliable estimate of which can yet be made. The Census of 1870 gives the number of 29,025 Indians in Cal-

ifornia, of which 7,241 were out of tribal relations. This nearly coincides with the estimate of the missionaries seventy-five years ago, but would show an incredible loss during the last seven years whereas most of the known decrease occurred before 1870. No statistics on the subject are reliable, but even admitting that 10,000 Indians may have been destroyed during the last quarter of a century, it must be considered that the circumstances were wholly exceptional. The crime was not accomplished by white civilization, but by white barbarity. In most other districts the pressure, though steady, was comparatively slow; the pioneers, themselves yet weak, were in contact with warlike tribes, and at first on their good behavior, even when their personal character might not have been just and humane. In California a horde of robbers burst like a tornado upon natives partly weaned by missionary efforts from distrust and the use of arms, at a time when Lynch law was the only tribunal, and the Vigilance Committee a blessing to the whites themselves. However the diminution of the race in that State may affect the census, it cannot be allowed to influence the decision of any question regarding its decay through the advent of civilization.

During the last three years, and only for that time, has there been any official report of the births and deaths among the several tribes, sufficiently general to be of value. Those for the period mentioned have been tabulated, and the averages taken from the returns relating to over 100,000 Indians, by Mr. S. N. Clark, of the Bureau of Education, and lately published in a pamphlet[4] upon Indian Civilization and Education, issued by General John Eaton, as representative of the Department of the Interior at the National Exhibition of 1876.

In 1874 the births were 4.48 per cent.; deaths 2.32 per cent.; net increase 2.15 per cent.

In 1875 births 2.55; deaths 1.57; increase .98, or nearly one per cent.

In 1876 births 2.91; deaths 2.31; increase six-tenths of one per cent.

These averages were not taken from selected bodies, but from the whole aggregate of births and deaths reported, which were from nearly one hundred tribes, or parts of tribes; yet as the

[4] This pamphlet was issued after the reading of this paper, but the contents of it now used had been kindly furnished to the writer before, and acknowledged in the paper when read.

more civilized tribes have been the more accessible to the official reporters, whatever of increase is shown must be among them as well as among the wilder, by no means a large proportion of the latter being embraced in the returns. The wars of 1875 and 1876 not only swelled the known deaths, but by confusion and displacement prevented the enumeration of births, these causes producing a slight falling off in the increase of those years from the average of 1874. The tribes in the Indian Territory, among whom at once the growth is admitted to be thoroughly established and who are the most advanced in civilization, are not included in these statistics but would surely swell the percentages.

When a fact is ascertained, reasons to account for it sprout up with gratifying profusion. Among several (besides the improvement in shelter, food and clothing, which never fails to be beneficial to health and longevity after the first critical change of habits is overcome) that might be adduced to explain why the present condition of many tribes would naturally tend toward increase, is one founded on the changed value of their infant, infirm and aged members. Their former main object was to enhance warlike force for the moment and the near future. The old and helpless were military *impedimenta* and often left to death, if not assisted thither in mercy as well as necessity. The doctrine of the survival of the fittest was strictly carried out by the destruction of unpromising children; and when births occurred at untoward times, the inconvenience was not allowed to continue. No occasion appeared favorable to the rearing of twins, one of them being as a rule killed or exposed. In the frequent emergencies of their precarious life, even apart from active warfare, the weak were generally sacrificed. When, however, rations, gratuities and annuities became attainable by the heads of families in proportion to the size of the latter, all its members, before a source of weakness, became elements of gain, and were cherished because they could be counted. Not only would such low and crafty motives operate, but the individuals of a family, who from age or malformation were useless in war and the chase, became of actual and legitimate value in agriculture and such manufactures as were attempted. The influence and fear of surrounding whites also tended to break up the cruel customs, in the continuance of which no special or selfish interest was gratified, and thus the ratio of births to deaths was enhanced, which the causes indicated had for ages tended to depress.

The Joint Committee, in 1867, while grudgingly admitting the increase of the tribes in the Indian Territory, declared it to be exceptional, and assigned as one of its causes that those Indians had from their earliest history kept herds of horses, which statement would seem to imply remarkable ignorance as to the date of the reintroduction of that animal. The Cherokees, however, could not have obtained horses, in any large number, much sooner than did the Cheyennes and Dakotas, and not so early as the Apaches and Navajos. A few years ago the advocates of slavery attributed the progress of these same Cherokees to that civilizing institution, which argument is not now so much in vogue. The simple truth is that the Creeks, Cherokees, Chicasas and Choctas, have, like the Iroquois, been for a longer period than most other tribes without molestation and continual deportation. Though some of them were early driven from their homes first known to us, they had a fair halt in Tennessee, Georgia, Alabama and Mississippi, when the tide of emigration rolled by and left Missouri, Arkansas and Louisiana interposed between them and the attacks directed upon victims still farther west. By this rest they obtained a start in culture, which continued after they had been removed to their present reservations; and they illustrate the fact that whenever a tribe has been permitted to be stationary for any considerable time, and has enjoyed a season of repose from invasion and legalized injustice, it has correspondingly increased.

The arguments of the Joint Committee, and of the authorities it quotes, amount to but the safe assertion, that when human beings are starved and butchered, demoralized and pauperized, they will decay in numbers and character. The Report flourishes a smart generalization that the Indians adopt the vices of the whites rather than their virtues. It should be remembered that other races have been once ignorant of agriculture and averse to regular toil, and it has required thousands of years for the maturity of their culture, from the point already reached by the tribes when first met by us. It is silly to expect a sudden improvement among any people by the *presto change!* of political conjuration, when their old modes of life are forbidden and none furnished instead; when their hunting grounds are fenced in or cleared of game, and their rivers dammed and polluted; when, without instruction in agriculture, they are coralled on soil so poor that the most industrious Dutchman scorns it as a free gift; when they are tempted

with whiskey and trinkets in a consistent plan for the gain of traders and land-sharks; when the price of home and blood is doled out irregularly, so as to insure pauperism and preclude attempts at steady work on the grudged spots whence they are ever hounded away, first by squatters and next by soldiers, against the plighted faith of treaties. Remorseless speculators and ignorant legislators have in fact done their best to prevent any improvement among the Indians, and to hasten the extermination which they sometimes avow that they would welcome as a national blessing; but, fortunately, enough tribes and bands have, through amazing energy and by taking advantage of some respites from persecution, proved their fitness to be regarded as future useful citizens. Consul Blake takes direct issue with our Solons in Joint Committee, showing that "in the more settled parts of Canada they have passed through the critical stage, and the assimilation of their habits to those of the white race, so far from threatening their gradual extinction, is producing results directly opposite." The same is true in this country, where it has been permitted by a cessation of robbery and "transplanting" to be physically possible. The Seneca and the Chocta now take prizes in agricultural fairs. The Cherokee legislature would be a good school in decorum and common sense for our House of Representatives; and some of the Reservations, for observance of law, interest in education and success in useful industries, compare favorably with our white frontier population. There is nothing exceptional in the character of the Iroquois or the Cherokee to account for his emerging from the perishing class into assured prosperity. Portions of the fierce Dakotas and the haughty Sahaptins have shown the same adaptability. If they can, so can all. At any points where the race is now degraded and diminishing, it is not from an irrepressible conflict with civilization, but with civilization's unworthy local and Washington representatives.

The conclusions submitted are, that the native population of the territory occupied by the United States at its discovery has been wildly over-estimated — that while many of its opponent bodies have diminished, or been destroyed by oppression and violence, their loss has been in large part compensated by gain among others—that the "blight" and "withering" or *ferœ naturæ* theory is proved absolutely false, and that though some temporary retrogradation must always be expected among individual tribes at the crisis of

their transition from savagery or barbarism to more civilized habits, yet now, the number of our Indians is on the increase and will naturally so continue, unless repressed by causes not attributable to civilization, but to criminal misgovernment, until their final absorption into the wondrous amalgam of all earth's peoples, which the destiny of this country may possibly effect. Neither from views of their physiological, religious or sociological characteristics should they be regarded as an exceptional or abnormal part of the human race, or so treated in our national policy. Only those legislators and officials who are prepared to encourage downright murder can neglect their duty under the Satanic consolation of the convenient extinction doctrine. With continued injustice, more Sitting Bulls and Chief Josephs, driven into the last refuge of despair, will require expenditure of blood and treasure which simple truth and honesty would not only prevent, but would preserve, reclaim and elevate a race intrusted to our national honor, which may readily and with no long delay, become a valuable element in our motley community.

TITLES OF OTHER PAPERS READ IN SUBSECTION OF ANTHROPOLOGY.

INTRODUCTION TO THE STUDY OF THE INDIAN LANGUAGE. By J. W. POWELL, of Washington, D. C.

REPORT ON THE EXPLORATION OF THE GRAVES OF THE MOUND BUILDERS IN SCOTT AND MISSISSIPPI COUNTIES, MISSOURI. By HORATIO N. RUST, of Chicago, Illinois.

SOME OBSERVATIONS ON THE SKULL OF A COMANCHE. By T. O. SUMMERS, jr., of Nashville, Tenn.

ON THE ANCIENT EXCAVATIONS IN WESTERN NORTH CAROLINA. By ALEXIS A. JULIEN, of New York.

ON THE ORIGIN OF THE JAPANESE. By SHUJE ISAWA, of Cambridge, Mass.

EXECUTIVE PROCEEDINGS

OF

THE NASHVILLE MEETING.

HISTORY OF THE MEETING.

At the Newport meeting, held in 1860, it was voted to accept the invitation from Nashville to hold the meeting for 1861 in that city. With that year, however, came the unhappy state of affairs in the country which prevented the Association from holding a meeting for five years. In 1866 the fifteenth meeting, which was to have been held in Nashville, was called by the Standing Committee to take place in Buffalo, and the meetings have been held annually since that time with constantly increasing importance and interest. In 1875 the invitation from Nashville was renewed with such cordiality by the citizens that it was almost impossible for the Association to decline the invitation for the following year. Had it not been for the necessity of holding the meeting of 1876 at a place easily accessible from Philadelphia, the centre of scientific interest during the Centennial Exhibition, the invitation, undoubtedly, would have been accepted. When the Association was assembled at Buffalo for the second time, the invitation from Nashville was renewed and unanimously accepted. The twenty-sixth meeting of the Association, therefore, was held at Nashville, Tennessee, beginning on Wednesday morning, August 29, 1877, and closing on the Tuesday night following.

Notwithstanding the dread of the summer heat, which naturally would be expected at a place so far south as Nashville, many northern and eastern members were present; the attendance of registered members at the meeting being only one-fifth less than at Buffalo the year preceding, and the heat which so many had feared to encounter was not found more oppressive than at several previous meetings in eastern localities.

The cordial manner in which the Association had been invited, the unusual interest taken in the meeting by the citizens, and the open-handed hospitality with which every member was welcomed, united with the excellent arrangements made for the personal comfort of members, and the convenience of places of meeting in the cool and delightfully situated Capitol, all combined to make the meeting one long to be remembered by those present. The only regret expressed was caused by the absence of northern and eastern members who were unable to undertake so long a

journey in the heat of August. This regret was greatly increased when it was known that the Retiring President, Professor Rogers, and the Vice President elect of Section A, Professor Pickering, would be prevented from attending on this account. The forced absence of Professor Rogers was deeply felt, as he had been so long identified with the development of science in the South as to be regarded as essential to the success of the meeting; but his cordial and cheering letter showing his continued interest in the Association and assuring his southern friends of his well-founded hopes of a successful meeting, in a measure relieved the feelings of the members and subdued the regret which was expressed for the loss of the cheering words of fellowship he would have given in person had his health permitted.

The generous hospitality of the citizens of Nashville has never been excelled at any former meeting, while the arrangements made by the Local Committee were not only complete in relation to the business of the meeting, but in regard to entertainments and excursions were of a very extended and generous character; making it indeed difficult for the members while striving to perform the duties of the meeting, to accept the many invitations which were so cordially extended to them. The hope that this meeting would again bring into the ranks of the Association the southern men of science who had returned but slowly since the meeting of 1866, was shown to be well founded, and Dr. J. Berrien Lindsley, the Local Secretary, and one of the southern founders of the Association, who had maintained his membership intact, succeeded in bringing to the Association even a larger number of southern members than was anticipated. With this increase of membership from the south and the additions that may be expected at the St. Louis Meeting, the national character of the Association is assured and all sections of the country, hereafter, will be well represented at its meetings. In this connection it is a pleasure to record the interest taken by the southern press in the objects of the Association and the valuable aid thus given to the Local Committee. To the editors of the *Nashville American* is this acknowledgment particularly due, not only for their efforts in making known the character of the Association previous to the meeting, but also for their care in reporting the daily proceedings with a fulness and accuracy which has seldom been equalled.

By the action of the State authorities, the Local Committee secured the Capitol for the use of the Association, and every facility possible was given by the State officers. To Colonel Gibbs, the Secretary of State and acting Governor during the absence of Governor Porter, the members were under constant obligation for the interest he evinced in the Association and his desire to do all in his power personally and officially to add to the cordial welcome extended by the Local Committee. To Mr. Glover, who had charge of the Capitol, the members were also indebted for many personal favors conferred in a manner so acceptable as to make the recipients doubly grateful for them.

Rooms in the Capitol for the various purposes of the Association were

assigned as follows: — Headquarters of the Local Committee and Association Post Office, in the Adjutant General's office, on the first floor; Office of the Permanent Secretary, in a side room opening into the Hall of Representatives; Standing Committee, in a room adjoining that of the office of the Permanent Secretary. The General Sessions were held in the Hall of Representatives, which was appropriately decorated by the Local Committee and daily furnished with beautiful flowers by the ladies of Nashville. Section A was assigned to the Senate Chamber, and Section B held its meetings in the Hall of Representatives after the morning adjournment of the General Session. Subsection C had the Supreme Court Room, Subsection D the Law Library, and Subsection E the room of the Commissioner of Agriculture. Other rooms were used for special committees and various purposes. In this manner was carried out the important object of having all the meetings and offices under one roof, in spacious, convenient and comfortable rooms, not far removed from the hotels and private houses where the members were quartered. The Maxwell House was the headquarters of the Association when not in session, and here special rooms for the use of members and committees were provided by Mr. Fullton, the proprietor, who, with the clerks of the house, was ever ready to add to the comfort of his guests. Many of the members were privately entertained, though the liberality of the citizens was so great that it made little pecuniary difference to the members whether quartered at the hotels or entertained at private houses.

One hundred and seventy-three members signed the register and were in attendance at the meetings, which were also largely attended by the citizens, who showed great interest in the scientific proceedings of the Association as well as in the social gatherings. This continued reunion of citizens with members from various parts of the country, was productive of the happiest results in a scientific as well as social point of view, and exemplified the wisdom of fostering the popular character of the Association as a means of advancing science by diffusing it among the people. As the control of the Association was kept within due scientific limits, the time of all interested was not often taken up by papers and discussions of little interest or importance.

Eighteen members of the Standing Committee were present; among them were three past Presidents and all but three of the officers elected for the Nashville meeting.

Two hundred and nineteen new members were elected. Of these one hundred and sixty have perfected their membership, eight have declined, notice has been received of the decease of one, and fifty have not yet answered the notifications informing them of their election.

The notices of the death of ten members were read. Thirty members were elected as fellows. Up to this date six hundred and seventy members have paid their assessments for the Nashville meeting.

Ninety-three papers were entered by title for the meeting; of these fifteen were either withdrawn by their authors or did not pass the Standing Committee for want of abstracts or from not being considered as

appropriate to the objects of the Association. The remaining seventy-eight were mostly read in full or in abstract and were divided as follows: — in General Session, three; in Section A, sixteen; in the Subsection of Chemistry, fourteen; in that of Microscopy, seven; in Section B, thirty-eight, of which eight came from the Subsection of Anthropology. This Subsection was united with Section B, one day being specially devoted to anthropological papers. Of the papers read and accepted by the Standing Committee for publication either in full or in abstract, many were not received by the Permanent Secretary, to whom all papers read at a meeting should be sent within a month after its adjournment. Owing to the regretted ill health and absence of the Retiring President, the customary President's Address was not delivered. At two General Evening Sessions the addresses of Vice Presidents Pickering and Marsh were read in full, the former by Professor Thurston in the absence of Professor Pickering. In the absence of Dr. Wilson, his address as Chairman of the Subsection of Anthropology was read by the Permanent Secretary, at the opening of Section B on the anthropological day. Professor Lupton and Dr. Ward opened their respective Subsections of Chemistry and Microscopy, by brief remarks. The Entomological Club of the Association was not very numerously attended, but the members specially interested in this department of research held several evening meetings at the Maxwell House, and, acting upon the reports of the Special Committees, particularly that on Nomenclature, continued the organization. General Sessions were held every morning, and on Wednesday, Thursday, Monday and Tuesday evenings.

Sections A and B, and the Subsection of Chemistry were organized on the first afternoon, and held sessions for the reading of papers on every day following. The Subsection of Microscopy held sessions on Friday and Saturday and gave a very interesting soiree on Monday night, at which time the large Hall of Representatives was filled with members and citizens.

To the energetic Local Committee the great success of the meeting is largely due, and though the Committee were unsuccessful in making arrangements with the railroads by which members from a great distance would be saved the expense of travel, except in the case of a few lines managed by the more liberal companies, they were extremely successful with the local railroad companies who fully appreciated the importance of the meeting and offered many facilities and liberal concessions. Particularly was this the case on the excursions, which were so generously seconded by the officers of the southern railroads as to enable the Committee to offer to the members of the Association the opportunity of visiting many localities not only free of expense but under the most auspicious circumstances. Never, in the annals of the Association, have been enjoyed such extended excursions as those given after the adjournment of the meeting, affording as they did to many of the members, a rare opportunity for becoming acquainted with the great natural resources and beauties of the South. Not only did the Local Committee thus enable

the members from the East and North to appreciate the natural wealth and scenery of the Southern States, but it provided for them the delights and advantages of social contact with the citizens of Nashville and vicinity by securing a series of receptions and entertainments at the beautiful homes of several of the leading and wealthy people, and at the various State and other educational and beneficent institutions.

To mention all the excursions and receptions in detail would cause this "history of the meeting" to fill more space than is allowed in the volume, and therefore allusion only can be made to the brilliant reception given in honor of the Association at the Maxwell House, by the Tennessee Historical Society, on Friday night; to the cordial greetings extended at the afternoon receptions at the beautiful homes of Dr. W. A. Cheatham and Mrs. A. V. Brown on Thursday and Friday; to the reception at the Vanderbilt University on Friday afternoon, and to the visit at the Tennessee Hospital for the insane where the extensive and well arranged buildings and grounds were appreciated. At all these places the members met with a truly Southern welcome, and were sumptuously entertained. Among other pleasant occasions was the call made by the Association on Mrs. Polk, who received the large delegation in an informal manner.

Many other visits were made by small parties of members, as opportunities offered, and the home of Jackson, the Fisk University, the Medical College, the Normal, Theological and other city schools, the churches, the Young Men's Christian Association, the National Cemetery, and many other places of interest were visited in that way. Numerous invitations were also extended to the Association from places at a distance, which time did not permit the members to accept; among these were the Prehistoric fort at Manchester, the Central Tennessee College, and the Mines of the St. Bernard Coal Company at Arlington, Kentucky.

The Association adjourned after the General Session on Tuesday night, but the kind attentions of the Local Committee and the people of the Southern States, did not cease with the meeting. Early the next morning a party consisting of over one hundred members, accompanied by several of the Committee and distinguished citizens started, in a special train furnished by the Chattanooga Railroad Company, on an excursion to Chattanooga, having accepted the invitation of the citizens who had extended to the Association the hospitalities of the city. At Chattanooga the party was received by Mayor White, General Wilder and many other citizens, who, after a most cordial greeting, conveyed the delegation to the Stanton House, which is located on a hill commanding a fine view of the surrounding country. Here the party was entertained, and every comfort that could be desired was found at a luxuriously furnished hotel kept by the most courteous and obliging of hosts. In the evening an informal meeting was held and addresses were made by Professor Cope, Major Powell and others, including several citizens. The next day, excursions were made to Lookout Mountain and other places. The various battle grounds and other historical places were pointed out, while the naturalists of the party had an opportunity to study the natural history of

this region, particularly interesting to the geologists and botanists. The numerous smelting works and foundries of this thriving city were also visited during the stay of the party who were constantly in receipt of unexpected courtesies.

At Chattanooga the party of excursionists divided, some returning to their homes and others entering on the more extended excursions that had been arranged by the Local Committee. One party, under the charge of Gen. Wilder, made the trip over the mountains of North Carolina and passed a week in that beautiful and geologically interesting region. Another party made a four days excursion to Birmingham, Alabama. The most extended excursion was that to Texas, and on this between twenty and thirty members embarked under the immediate charge of the Local Secretary and Professor Cope. This excursion had been especially planned by Ex-Governor John C. Brown of Tennessee, who was indefatigable in perfecting all the arrangements; and through his efforts, seconded by the officers of the several railroads over which the excursionists were conveyed, a trip of about three weeks in duration and extending as far south as San Antonio, Texas, was enjoyed to the fullest extent by the party, without care or expense. In Texas, and at the several stopping places on the route, the party was most cordially greeted. At some of the stopping places impromptu meetings were held and addresses and scientific communications were made. From this excursion the party returned loaded with specimens illustrative of the natural history of the region passed over, surprised at the natural resources of the great state of Texas, and highly pleased with the kind reception everywhere extended. A full account of these excursions will be published by several gentlemen in Nashville, in a volume which the Southern friends of the Association hope to prepare as a lasting memorial of the visit of the Association. Other members of the Association, with special objects of research in view, did not go on the general excursions, but remained in various parts of the state of Tennessee for some time after the meeting.

I cannot close this incomplete sketch of the very successful meeting at Nashville without a word of personal thanks for the many courtesies everywhere extended to me in furtherance of my own particular researches in the prehistoric remains of this important region so interesting to the student of American Archæology. Remaining in the state as I did for nearly a month after the adjournment of the meeting, and receiving such cordial support in my work, I was enabled to make many observations and extensive collections.

F. W. PUTNAM,

Permanent Secretary.

REPORT OF GENERAL SECRETARY.

The Association met in the Hall of Representatives, Capitol Building, Nashville, Tenn., at 10 o'clock, A. M., Aug. 29, 1877. The meeting was called to order by Prof. James Hall in the absence of the retiring President, Prof. William B. Rogers.

The Permanent Secretary then read the following letter:

Newport, Aug. 22, 1877. — Prof. F. W. Putnam, Permanent Secretary A. A. A. S. — Dear Professor: I have at last and most reluctantly yielded to the counsel of physicians and friends and given up my purpose of attending the Nashville meeting. I say most reluctantly, for besides having the pleasure of being with my old friends of the Association, I had hoped to meet our scientific brethren of the South, of whom some were my former pupils and dear friends, whose hands I should be delighted again to grasp, and all of whom I should be happy to assist in welcoming into the ranks of the Association.

Had I been able to write the address, for which I was preparing early in the summer, I should, I think, have taken the risk of presenting myself at Nashville, though only for a day or two. But the nerve-exhaustion to which I have for many years been liable, aggravated by the season, compelled me soon to suspend, and finally to give up the work.

I have, as you know, felt an especial desire to attend this meeting, in favor of which I used what influence I had last year at Buffalo. For I have long believed that the interests of the Association, and what is far more important, those of the science and education of our country at large, would be greatly promoted by whatever should secure to the Association the sympathy and coöperation of the teachers and cultivators of science and the educated men generally of the Southern States.

From personal knowledge of the South, I feel assured that the Southern Universities and Colleges and their Alumni are ready to contribute largely to the scientific activity as well as to the numerical force of the Association, and I cannot doubt that the Nashville meeting will give proof of the heartiness with which they desire to coöperate in its truly national scientific labors.

It is surely no mere dream of patriotism to believe that the interchange of knowledge and sympathy by enlightened men from all parts of our country, will do much to foster among our fellow citizens at large that strong sense of fraternity which, more than all constitutions and laws, must form the basis of our permanent unity and greatness as a nation.

While regretting that I shall not have the opportunity, afforded by the usual formal resignation of the chair, of expressing in person to the Association my thanks for the consideration it has shown me, I desire to offer it my congratulations on the happy auspices under which it has assem-

bled, in having for its President an astronomer, whose scientific genius and labors are honored in both hemispheres, and who enters upon his duties at the moment when American Astronomy is illustrated by one of the most brilliant discoveries of recent times.

With heartiest wishes for the success, both social and scientific, of the present meeting, and a renewed expression of my regret at not being with you, I remain, dear Professor, yours faithfully,

WILLIAM B. ROGERS.

The CHAIRMAN in a few appropriate words introduced the President elect, Prof. SIMON NEWCOMB; the latter, on taking the Chair, spoke as follows:

LADIES AND GENTLEMEN OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE: — I beg to accept, with the assurance of high appreciation, the honor which you have conferred upon me. That appreciation is only dampened by a single reflection: I fear that in your choice charity shines rather more than wisdom. You have called to these duties one whose whole course of study and habits has unfitted him from properly filling the position. Universal genius and the capacity for doing all things are not given to any one man. He who attempts it will probably fail in everything. It happens not unfrequently that these special habits of thought, and that course of study and education which develops the powers in one direction, and those investigations in order to succeed in that certain line, are not only of no benefit in another line, but an absolute disqualification. And it may happen that one who has been accustomed only to act after long and careful deliberation may find himself at sea, when promptness and decision become absolutely necessary.

I shall have to ask you, therefore, for your forbearance with me in performing the duties of this office. There is perhaps, one consoling reflection: I think this is not an Association over which it is a very difficult matter to preside. We are not torn by conflicting influences nor by internal dissensions of any kind, and I hope that that fact will enable me to go through successfully.

I must say a word to you on our meeting in a Southern city for the first time in a period of nineteen years: I hope that this will more truly nationalize the Association, and that our meeting here may be followed by an acquaintance with scientific men who will long be remembered by us.

An invocation was then pronounced by the Rev. Dr. SUMMERS, after which the PRESIDENT introduced the Hon. THOMAS A. KERCHEVAL, Mayor of the city of Nashville, who welcomed the Association in the following words:

LADIES AND GENTLEMEN AND MEMBERS OF THIS ASSOCIATION: — It is on behalf of our city that I am with you this morning, to extend a most hearty and grateful welcome, and to express the hope that while you remain in our city you will enjoy yourselves and be treated with all the kindness and hospitality that you so much deserve. This Association,

being composed, as it is, of the most learned and scientific men of the nation, has gone forward and delved into the resources of nature and developed the sciences — has done a great deal towards enlightening the people. And, while we are not able to show you as large and beautiful a city as the one from which many of you have come, yet to make up for that we will extend to you all the hospitality of which the Southern people are capable. Therefore, hoping that this Association may have a pleasant meeting, and that its work may go forth to the benefit of the country, and that you may carry away with you pleasant memories of a kind and hospitable people, again I bid you welcome.

The PRESIDENT then introduced Judge JOHN M. LEA, who addressed the Association in behalf of the Governor and people of the State of Tennessee as follows:

Our distinguished Governor, whose absence deprives him of the pleasure of addressing you on this interesting occasion, requests me in his name and in the name of the people of the State, to extend to you a most hearty and cordial welcome. We appreciate, indeed, the honor conferred upon our State and city by an assemblage, the members of which, deeply impressed with the love of science and lightly esteeming the ordinary objects of human ambition, devote their lives to the acquisition and dissemination of knowledge. No aspiration for worldly fame, nor hope of individual emolument, nor even the advancement of any industrial enterprise, brings together this large and intelligent assembly, the sole aim and purpose of which is to establish and promulgate truth as revealed by science. These annual reunions not only mark the progress, but widen the area, of human knowledge, for, while a transcript of your proceedings contains a registry of all previous conquests over the domain of nature, each recurring meeting opens up, through the instrumentality of your investigations, new sources of information which had hitherto eluded the industry of former observation. In commercial phraseology, this Association annually declares a dividend of knowledge, the result of the cheerful and unrecompensed toil of its members, in which dividend more precious than gold, "yea, than much fine gold," the people of every age and nation participate as joint and equal owners. The ascertainment of truth is the mission of science, and that mission, far from conflicting with any principle of religion, strengthens our conviction in the existence of "a great first cause" which regulates, with a wisdom surpassing all human comprehension, the proper disposition and orderly arrangement of every particle of matter in the heavens above or on the earth beneath — guiding and controlling alike the fall of the leaf from the tree and the motions of the planets in their orbits. How erroneous and even absurd would be our conceptions concerning the mechanism of the little globe on which we live, if the astronomer had not fixed our point in space, the chemist had not taught how few are the elements of which its mass is composed, and the geologist had not proved that the confusion apparent in its economy is, in fact, but an exhibition of the beautiful and methodical succession of natural causes. A new light dawned and a new impulse

was given to the mind when a love for science superseded the foolish admiration for the scholastic philosophy of the middle ages; and, since that happy change of thought into this new direction, how great indeed has been our progress — and how much greater will it be in the distant future, for there is no limit to be assigned to the accumulation of knowledge in succeeding ages. We, therefore, in common with the enlightened sentiment of the world, commend the labors and acknowledge our obligations to the promoters of science.

The presence of distinguished persons from different portions of our broad and diversified but united country is, indeed, to us the source of gratification, but our pleasure in your visit at this particular time is enhanced by the reflection that your example, more powerful than precept, cannot prove otherwise than conducive to a fuller development of that growing sentiment in the interests of general education which is beginning to pervade our community. Our gratitude for collegiate endowment is chiefly due to private munificence, but the State has not been altogether unmindful of her duty; and a territorial grant of land, made so long ago as 1789, furnishes support for a Normal College, a recently established and most flourishing institution. There are other seats of learning in different parts of our State, one the recipient of large favors from the General Government, others under the patronage of Christian denominations, while, from the acropolis on which this Capitol is erected, the eye takes in at a glance three magnificent structures also recently established and dedicated to the cause of letters. These institutions are yet "in the marrow, not hardened into the gristle of manhood," — their position in the literary and scientific world is yet to be taken — their *prestige* to be won — but ample endowments and satisfactory management give promise of future success. But our admiration for the erudition of the University has not caused us to be insensible to the claims of popular education, and we are happy to say that in our State the support of the public school is equally a pleasure and a duty. These evidences of our sensibility to intellectual culture, for we make little pretensions to advancement, attest that, in some measure, at least, we may appreciate the essays and papers to which, with so much pleasure and improvement, we expect to listen during the session of the Association.

Not entirely, however, is it on account of your eminence in learning, nor our interest in education, that we express satisfaction at your coming among us. We are friends, though strangers — the citizens of a common country, and we hope you will not become so absorbed in business that there will be no time left for the interchange of social civilities. We should like you to see something of our State, which it is pardonable in us to think compares most favorably in all the elements of greatness with any of her sisters. There is East Tennessee with its lofty mountains and deep ravines, its magnificent scenery, the Switzerland of America, and from the variety and abundance of the minerals which lie buried in its bosom, might, also, with equal propriety, be called the Wales of America — a land of beauty and grandeur, "where looks the cottage out on a

domain the palace cannot boast of." Here is our middle section, with its fertile soil now garnished with verdure or waving with gold harvests, renowned for the variety and excellence of its agricultural productions; and beyond the river which gives our State its name, lies a rich and thriving country, the most northern limit for the cultivation of that staple, the manufacture of which gives bread to the operatives at Manchester, and puts in motion the wheels and spindles of your New England factories, the western border of which is fringed by that gigantic stream which drains the vast regions between the Alleghanies and the Rocky Mountains. Our land, too, is rich in antiquities, and seems to have been the favorite abiding place of the Red Man, and also of the race which preceded him. Relics abound, and we fancy we can tender a field of interest — special interest to the archæologist. All these we should like to show you, if you will give us an opportunity; and now, in conclusion, inviting you to our homes and our houses, let me express the hope that the memory of your sojourn in our city may be agreeable to you, as I know it will be to the citizens of Nashville, in whose name I give the kindest greetings.

To these addresses of welcome, the PRESIDENT responded as follows:

As the organ of the Association on the present occasion, I beg leave to assure you of the very high appreciation which is entertained of the very cordial welcome which you have given to us. You have successfully rivalled, if not completely outdone, the more populous communities among which the Association has heretofore met. For this, thanks are no doubt due both your citizens and your Local Committee, and I beg that they will both accept them.

For the first time in a long period the Association meets here in the Southern States, at perhaps a greater distance from the homes of most of the members than is usual. If it should happen that the numbers in attendance do not correspond to your exertions, and do not quite fulfil the hopes which you have expressed as to the numbers attending the meeting, I hope you will remember that this is a season when the human body gravitates toward the pole, and when men look with extreme aversion in the direction of the equator. This must be our excuse, perhaps, for the fewness of the meetings which we have so far held in the Southern States.

Since we have before met you the country has been torn by internal dissensions. A great amount of reconciliation and reconstruction of broken associations has been necessary. If this was necessary in our Association, also, if the long period during which we have been parted was one of estrangement, then, indeed, we should have to admit that the Association would have done very much better if they had continued the term of my honored predecessor to the present day, because it is his tongue alone whose eloquence would have been equal to the occasion. But I am happy to say that in the present case no expression of joy over any such reconciliation or reconstruction is necessary. The purpose of science is solely the discovery of knowledge for the benefit of mankind. Its interests are as wide as humanity, and its field includes the heavens as well as the

earth. It is, therefore, an eminently fitting fact that the fumes of the political cauldron never rise up in our midst. Nothing of a political nature estranges the workers of science from each other. We have no "erring brethren" to welcome back in our midst. This is the spirit of science, not only the world over at the present, but it has been its spirit during a period which goes back into the dark ages. It has no martyrs to bear upon its roll. No punishment has been inflicted in the name of science in any part or age of the world.

A few years ago it was my fortune to be in Paris at a time when that celebrated Commune was in full sway. In the reaction which followed the downfall of Louis Napoleon, the populace was engaged in destroying every remnant of monarchy. The mystic letter "N" was torn down, and even the names of streets which savored of monarchy displaced. One day I was being shown through the rooms where the Academy of France held meetings. I noticed in a prominent position a picture bearing the well-known face of the great warrior, and under it "Napoleon Bonaparte, First Consul." I expressed my solicitude as to that picture remaining there. Why it happened to remain there was met by the emphatic response, "Politics never enter here." Thus, during the seventy years of internal turmoil among the most excitable people known, in an association which contained extremes of both parties, that picture had remained untouched during the revolutions which had affected the Government of France. This is the spirit of science everywhere.

Now, I presume, I may venture to hope that we may do some little benefit to you as well as to ourselves by coming amongst you at the present time. I hope that our meeting here will tend to strengthen the bonds of intercourse between the lovers of science and learning here and in the North. I hope you will long remember this meeting as an event in Southern progress; and that the hearty welcome, born of your sunny skies, which we of the North have not, will be remembered by us of the North during years to come; and although the people of the North are unable to excel you in warmth of welcome, it is, I assure you, on account of no lack of warmth of feeling. I again thank you for the hearty welcome which you have given us.

The GENERAL SECRETARY then announced the following invitations, which were unanimously accepted.

To visit the residence of Dr. CHEATHAM on Thursday afternoon from 3 to 6 o'clock.

To visit the grounds and building of the VANDERBILT UNIVERSITY on Friday afternoon.

To visit the NASHVILLE NORMAL THEOLOGICAL INSTITUTE.

To attend a reception given by the TENNESSEE HISTORICAL SOCIETY, at the Maxwell House, Friday evening.

To visit the TENNESSEE HOSPITAL for the INSANE on Saturday afternoon.

To visit Mrs. AARON V. BROWN, at her residence, on Monday afternoon.

To an excursion, tendered by Gen. WILDER on behalf of CITIZENS of CHATTANOOGA, to that city and vicinity, to take place upon the adjournment of the Association.

The PERMANENT SECRETARY then read the following invitations to hold the next meeting of the Association at St. Louis, at Cincinnati, and at St. Paul.

MAYOR'S OFFICE, ST. LOUIS, JUNE 11, 1877.

PROF. F. W. PUTNAM,

Permanent Secretary of the A. A. A. S.

DEAR SIR:—It gives me pleasure to renew the invitation extended to your Association August 8, 1876, to hold its coming convention in this city.

As stated then the restrictions of our charter prevent the expectation of my tendering any specific hospitality by the city as a municipality. But I assure you that the citizens of St. Louis entertain too high an opinion of the value of such a meeting in our midst, not to appreciate the pleasure it will afford them to make your visit agreeable and hospitable.

Respectfully,

HENRY OVERSTOLZ,

Mayor.

ST. LOUIS, JULY 6, 1877.

TO PROF. F. W. PUTNAM,

As Secretary of the A. A. A. S.

SIR:—The labors of your Association have created a noble interest in its objects. It is deeply felt in this city, and has prepared its spirit for a most needful baptism for an engagement in its grand mission. A meeting of your Association in it would greatly tend to accomplish this confirmation. In this belief the Missouri Historical Society of St. Louis has, unanimously, authorized and directed me, as its President, to send its request that the A. A. A. S. hold its next meeting in this city. This honorable duty I now most cordially perform through its distinguished Secretary.

The hospitable habit of this city will secure to your associates a hearty and happy welcome.

Very respectfully yours,

JAMES G. BRADY,

As President M. H. S., St. Louis.

DEPARTMENT OF THE INTERIOR, OFFICE OF THE U. S. ENT. COM.
WINNIPEG, AUGUST 25, 1877.

F. W. PUTNAM,

Permanent Secretary A. A. A. S.

DEAR SIR:—By unanimous vote of the St. Louis Academy of Science, I was instructed to renew the invitation to the Association, which I gave

last year, to hold its next annual session at St. Louis, and as I cannot be present at Nashville, I have left it with Prof. Nipher, Recording Secretary of the Academy, to properly present the claims of St. Louis.

Yours very truly,

C. V. RILEY,

Pres. St. Louis Ac. Sc.

WASHINGTON UNIVERSITY,
ST. LOUIS, MO., AUGUST 26, 1877.

F. W. PUTNAM,

Permanent Secretary A. A. A. S.

SIR:—The Chancellor of Washington University has authorized me to extend to the American Association for the Advancement of Science, a cordial invitation to hold its next meeting in St. Louis. It is thought that ample room for the various meetings will be found at the University buildings, which will be at the disposal of the Association.

Very respectfully,

FRANCIS E. NIPHER.

BOARD OF TRADE, SECRETARY'S OFFICE.
CINCINNATI, JULY 2, 1877.

L. S. COTTON, ESQ.,

Secretary Cincinnati Soc. Nat. Hist.

DEAR SIR:—Your communication asking the coöperation of this Board, in effort to induce the "American Association for the Advancement of Science" to hold its annual session for 1878 in this city, was presented to the Directors at their meeting on Saturday last and the following was adopted:—

"*Resolved*, That the Board of Trade fully recognizes the high character and elevated objects of the American Association for the Advancement of Science, and the desirability of inducing the society to hold its session of 1878 in our city. Believing, as we do, that the benefits will be mutual, and that the society will find the advantages offered by our city, in its central location, railroad facilities, hotel accommodations and magnificent public halls, to be unsurpassed, we join heartily in the invitation proposed to be extended by the Society of Natural History."

Very respectfully,

J. F. BLACKBURN, *Sec.*

CINCINNATI, JULY 5, 1877.

TO THE STANDING COMMITTEE OF THE AMER. ASSOC. FOR THE ADV. OF SCI.

GENTLEMEN:—The Young Men's Mercantile Library Association of Cincinnati hereby extends a cordial invitation to your society to hold its

annual session for the year 1878 in this city, or if it should not be possible to do this in 1878, then as soon as practicable thereafter.

We promise you a hearty welcome from all the Literary and Scientific Societies of this city.

Hoping for a favorable consideration of this invitation, we remain,

Very respectfully,

THE Y. M. M. L. ASSOCIATION.

By GEO. T. HARRISON, *Vice President.*

ACADEMY OF MEDICINE,
CINCINNATI, AUGUST 7, 1877.

TO THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

GENTLEMEN:—The Academy of Medicine of Cincinnati extends to your learned body a cordial invitation to hold your meeting for the year 1878 in our city. We think no city can surpass ours in accessibility, facilities for reception and entertainment, and in the general interest of the community in objects and associations of a scientific nature.

Yours truly,

A. G. DRURY,
W. W. SEELY,
GEO. B. ORR,
Committee of Invitation.

CINCINNATI COLLEGE OF PHARMACY
No 195 WEST FIFTH STREET.
CINCINNATI, O., AUG. 13, 1877.

L. S. COTTON,

DEAR SIR:—In relation to your communication asking the coöperation of this College in an invitation to the American Association for the Advancement of Science to hold its next annual session in this city, the following resolution was passed:—

Resolved, That as a scientific body we earnestly tender our hearty endorsement in the effort to secure the meeting of the American Association for the Advancement of Science in this city, and regard the holding of the Convention here as highly beneficial to the interests of Science.

Yours respectfully,

A. W. BAIN,
Secretary, C. C. P.

ZOÖLOGICAL SOCIETY OF CINCINNATI.
CINCINNATI, AUGUST 15, 1877.

SIR:—I am instructed by the Board of Directors to communicate to you the following Resolution, which was unanimously adopted at its last meeting:

"The Zoölogical Society of Cincinnati cordially unites with other societies in the city in an invitation to the "American Association for the Advancement of Science" to hold the next Western Session in Cincinnati, and will do all in its power to make the meeting pleasant."

I am also authorized to say that the Directors of the Zoölogical Society are happy to avail themselves of the opportunity now afforded by the Association meeting in Nashville, to extend an invitation to any of its members passing through Cincinnati to visit the Garden. Members of the Association will be admitted upon presentation of their visiting cards at the gate.

Very respectfully,

L. J. CIST,
Secretary Z. S. C.

ROOMS CINCINNATI SOCIETY OF NATURAL HISTORY,
47 AND 48 COLLEGE BUILDING,

CINCINNATI, SEPT. 1, 1877.

TO THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

The Cincinnati Society of Natural History extends to you a cordial invitation to hold your next annual meeting in this city.

R. B. MOORE, *President.*
J. F. JUDGE, *Recording Secretary.*

ST. PAUL, MINNESOTA, AUGUST 1, 1877.

TO THE PRESIDENT AND MEMBERS OF THE
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

GENTLEMEN:—The undersigned, appointed by Resolutions respectively of the ST. PAUL ACADEMY OF SCIENCES, the ST. PAUL CHAMBER OF COMMERCE, and the CITY COUNCIL OF ST. PAUL, designated to conjointly extend to the American Association for the Advancement of Science our most cordial as well as formal invitation to hold its annual meeting for 1878 in our city.

The central position of St. Paul in the northwest system of railroad and river routes, with its attractive surrounding natural scenery of waterfalls, lakes and prairies, and its geological, botanical and other features interesting to the scientist, cannot fail to make such a visit a pleasure; while our cool, bracing and salubrious climate will add strength and vigor to both mental and physical enjoyment.

It will be the united effort of our Academy, Chamber of Commerce, and City Government to make your visit mutually enjoyable and to attach us to each other, not only in friendship, but for the advancement of Science.

Very sincerely yours,

J. T. MAXFIELD, *Mayor.*

WM. R. MARSHALL,
JAMES SMITH, JR.,
C. H. BIGELOW, } *Committee of Chamber of Commerce.*

R. ORMSBY SWEENY, *President St. Paul Academy Sciences.*
D. A. ROBERTSON, *Vice President* " "
B. F. WRIGHT, *Chairman Chemical Section, A. S.*
HERBERT W. SMITH, " *Mineralogical Section, A. S.*

On motion, these invitations were referred to the NOMINATING COMMITTEE.

The PERMANENT SECRETARY read notices of ten Members and Fellows deceased since the last annual meeting.

Prof. ALEXIS CASWELL, Providence, R. I., died Jan. 8, 1877, aged 77 years. Professor Caswell joined the Association at its 2d meeting and has always been an active member. He was elected Vice President for the Montreal Meeting. Owing to the death of Prof. Bailey the president elect for that meeting, Prof. Caswell, presided, as he also did at the following meeting in Baltimore for which he was elected president.

Mr. EDWIN BICKNELL, Boston, died at Lynn, Mass., March 19, 1877, aged 47 years. He joined at the 18th Meeting and was very active in forming and maintaining the subsection of microscopy.

Mr. SAMUEL ADAMS, Gilead, Me., died April 29, 1877, aged 71 years. He joined at the 18th Meeting.

Prof. SANBORN TENNEY, Williams College, died July, 1877, aged 50 years. Joined at the 17th meeting.

Hon. WM. B. OGDEN, New York, died Aug. 3, 1877, aged 72 years. Joined at the 17th meeting.

Rev. EDWARD OTIS HOVEY, D. D., Crawfordsville, Ind., died March 10, 1877, aged 76 years. Joined at the 20th meeting.

Mr. F. B. MEEK, Washington, died Dec. 21, 1876, aged 59 years. Joined at the 6th meeting.

Prof. TIMOTHY ABBOTT CONRAD, Philadelphia, died at Trenton, N. J., August 8, 1877, aged 74 years. Mr. Conrad was an original member of the Association.

Prof. JAMES H. EATON, of Beloit, Wis., died Jan. 5, 1877. Joined at the 17th meeting.

WILBUR F. PARKER, of West Meriden, Conn., died in Jacksonville, Fla., in 1876. Joined at the 23d meeting.

The PRESIDENT then announced as the next business in order, the election of six Fellows to complete the Standing Committee. The following were then elected: Professors R. H. THURSTON, J. B. LINDSLEY, N. S. SHALER, J. M. SAFFORD, J. W. POWELL, and N. T. LUPTON.

The GENERAL SECRETARY announced the number of papers to be presented to the various sections which had been received. Also a list of one hundred and forty-eight candidates for membership, recommended by the STANDING COMMITTEE, after which these candidates were duly elected.

The CHAIR announced, as a recommendation of the STANDING COMMITTEE, that the morning sessions should close at 12.30 P. M., and the afternoon sessions begin at 3 P. M., which was adopted.

Announcements as to the places of meeting of the several sections of the Association were made and the General Session adjourned.

At 3 P. M. the Association met in sections. *Section A* organized in the Senate Chamber by the Election of Prof. R. H. THURSTON as *Chairman*,

pro tem., in the absence of Vice President PICKERING. *Secretary*, Prof. H. CARRINGTON BOLTON.

The organization was completed by the selection for SECTIONAL COMMITTEE of Professors T. C. MENDENHALL, A. A. JULIEN, F. E. NIPHER; and for members of the NOMINATING COMMITTEE, Professors E. W. HYDE, H. W. WILEY, R. H. WARD, A. P. S. STUART.

Section B assembled in the Hall of Representatives and was called to order by *Vice President* MARSH, Chairman of the Section. *Secretary*, Capt. W. H. DALL. The organization was completed by the selection for SECTIONAL COMMITTEE of Prof. E. T. COX, Maj. J. W. POWELL, Dr. GEO. LITTLE; and for members of the NOMINATING COMMITTEE of Professors E. D. COPE, E. A. SMITH, J. R. PROCTOR, and Dr. T. O. SUMMERS, jr.

Permanent Subsection C met and organized with Prof. N. T. LUPTON, *Chairman*. *Secretary*, Prof. PAUL SCHWEITZER.

Permanent Subsection D, in the absence of its Chairman Prof. DANIEL WILSON, decided to unite with *Section B*, on the understanding that Monday should be devoted by the Section to Anthropological papers.

In the evening the Association met in the Hall of Representatives and extemporary addresses were delivered by President NEWCOMB and Professor JAMES HALL.

At the conclusion of Prof. Hall's remarks the PRESIDENT spoke as follows:

These beautiful flowers by which we are surrounded are a tribute from the fair hands of several ladies of Nashville, who have taken this delicate way of showing their appreciation of the Association. I am sure the Association will authorize me, without formally putting it to a vote to present its thanks to those ladies for their very delicate compliment.

The PERMANENT SECRETARY then read a letter, enclosing a check for one hundred dollars, from Mrs. ROGERS, the wife of the retiring President:

An address upon meteoric stones was then delivered by Prof. J. LAWRENCE SMITH, after which Prof. A. R. GROTE read a paper on "On International Scientific Service."

The Second Day's Session opened in the Hall of Representatives at 10 A. M.

Invitations to visit various places and institutions were read by the GENERAL SECRETARY.

The recommendation by the STANDING COMMITTEE that the names of Prof. J. P. LESLEY and Prof. ANDREW C. RAMSEY should be added to the International Geological Commission was unanimously concurred in.

Thirty-eight candidates for Membership in the Association, recommended by the STANDING COMMITTEE, were then elected.

The PRESIDENT then announced that the sections would adjourn promptly at 12.45 P. M. to meet in the Hall of Representatives, and that the Associ-

ation would proceed thence in a body, at one o'clock, to pay its respects to Mrs. POLK, relict of the late JAMES K. POLK, President of the United States.

The Association then adjourned to meet in sections.

In the evening the Association listened to the address of Vice President MARSH, of Section B, in the Hall of Representatives.

The Third Day's Session opened in the Hall of Representatives at 10 o'clock, A. M.

Four candidates for membership, recommended by the STANDING COMMITTEE, were elected.

The President introduced Gen. WILDER to the meeting, who gave explanations of the details of the proposed excursion to Chattanooga. Professors SAFFORD and LUPTON followed on the same subject.

Prof. R. H. THURSTON offered the following resolution which, on motion, was referred to the STANDING COMMITTEE:

Resolved, That there shall be formed a Permanent Committee, to consist of five members and fellows, on the development of mineral resources and the encouragement of arts and manufactures in the mineral States, said committee to be appointed by the President.

The Association then adjourned to meet in sections.

The Fourth Day's Session opened in the Hall of Representatives at 10 o'clock, A. M.

Nineteen candidates for membership, recommended by the STANDING COMMITTEE, were elected.

Invitations to visit the NATIONAL CEMETERY, near Nashville, and to attend services at MCKENDREE CHURCH, were read by the GENERAL SECRETARY.

President NEWCOMB stated that heretofore it had been the custom to leave with some Literary or similar society a set (twenty-five volumes) of the Transactions of the Association, as a memento of its visits, but, in this instance, on account of the extreme courtesy which had been extended, he would suggest that two sets be presented — one to the VANDERBILT UNIVERSITY, and one to the TENNESSEE HISTORICAL SOCIETY. A motion to that effect was made and unanimously adopted.

Vice President MARSH moved to refer to the STANDING COMMITTEE the paper of Prof GROTE "On International Scientific Service," presented in the general session, Wednesday, as it was of very great importance. Adopted.

Prof. THOS. BASSNETT offered the following resolution, which was referred to the Standing Committee.

Resolved, That in the opinion of this Association the Superintendent of the "Nautical Almanac" would facilitate researches in the uncertain domain of physical astronomy, by giving a column on one of its pages, showing the systematic longitude of the sun's center and the values of radius vector for the first day of each month (or oftener, at his discretion) as computed for the action of the four great exterior planets, and that the Permanent Secretary be instructed to present this resolution at the close of this Convention.

After some announcements by the LOCAL COMMITTEE, the general session adjourned to meet in Sections.

The Fifth Day's Session opened in the Hall of Representatives at 10 o'clock, A. M.

Five candidates for membership, recommended by the STANDING COMMITTEE, were elected.

Thirty members were recommended by the STANDING COMMITTEE for election as Fellows of the Association, and upon a ballot being taken they were all duly elected.

Prof. SAFFORD stated that he had received the following preamble and resolutions from Dr. A. C. FORD, of the Signal Service:

Whereas, There is now in progress a plan of polar exploration and discovery, having in view the establishment of a colony at some point north of the eighty-first degree of north latitude, for purposes of scientific exploration and research; and

Whereas, No field offers to scientific toil more bountiful harvests than the comparatively unknown region of the frigid zone; and

Whereas, The scheme now successfully inaugurated by the sailing in July, of the present year, of the schooner Florence, carrying the preliminary expedition, has received the endorsement and warm support of the most famous Arctic explorers of this country and Europe, as well as prominent scientists of both continents: therefore be it

Resolved, that this Association, believing this expedition for Polar discovery, under the direction of Capt. HOWGATE, U. S. A., and other competent leaders, is likely to prove, in the highest sense, beneficial to science, as well as to reflect honor upon the nation, cordially approve the objects sought, and recommend it to the National Legislature as well as to the country at large, as deserving of hearty, earnest and liberal support.

The resolutions were referred to the STANDING COMMITTEE.

The GENERAL SECRETARY then read the following preamble and resolutions, which upon motion were referred to the STANDING COMMITTEE:

Whereas, A bill was passed by the Forty-first Congress, whereby the part of land in Wyoming Territory, known as "The Yellowstone National Park," was "reserved and withdrawn from settlement, occupancy or sale under the laws of the United States, and dedicated and set apart as a public park or pleasuring ground for the benefit and enjoyment of the people;" and

Whereas, The aforesaid park contains within its limits the most remarkable thermal springs and other features of interest to men of science known in any part of the world; and

Whereas, The Secretary of the Interior is charged by law with the preservation and maintenance of said reservation, but without any provision for the compensation for the fulfillment of other duties imposed upon him by the act of dedication; be it

Resolved, That we as Members and Fellows of the American Association for the Advancement of Science, in session in the city of Nashville, Tenn., do hereby respectfully petition the Congress of the United States that they give this important matter their most serious attention at an early date, that the work of devastation now progressing in that region may be stayed ere it has done irreparable injury to natural productions of the highest value in scientific investigation. Be it further

Resolved, That this subject, and the manner of so doing, be confided to a committee of five members of this Association conversant with the matter, whose duty it shall be to memorialize Congress in our behalf, to use all legitimate means for the furtherance of the objects here expressed, and to report upon them at the next meeting of this Association.

President NEWCOMB called for a report from the Permanent Committee on Weights, Measures and Coinage.

Prof. J. LAWRENCE SMITH stated that no special action had been taken by the committee, although he supposed next year, especially if the Paris Exposition came off, more progress would be made in that direction. He felt confident of the ultimate introduction of the metric system. Many schools were now instructed in it, and through the schools the French system of weights and measures must come into general use.

President NEWCOMB called upon the Committee appointed to Memorialize the New York Legislature for a new Survey of Niagara Falls, for a report, but there was no response.

The PRESIDENT also called for a report from the Committee appointed to Memorialize Congress upon the Cultivation of Timber and the Preservation of Forests.

Permanent Secretary PUTNAM stated that the committee had made favorable reports at two meetings. Printed reports had also been given in connection with Senate documents.

Dr. J. S. COPES, of New Orleans, said he was afraid the committee had considered the question of too little importance, and he would suggest that some addition be made to the committee to make it more efficient. That thing was very important, when the effects of the continued bareness of our country was considered. The French had made great progress in Algiers in the preservation and the restoration of forests, and their example should be followed here.

Capt. DALL stated that Prof. HOUGH, chairman of the committee had been devoting almost his entire time to this subject for more than a year, and visited Washington last winter entirely on that business. It required much time and labor to obtain the necessary information on which to base some practical measure for adoption by Congress. Prof. HOUGH had received from Congress some additional authority, and there was no question whatever that the chairman was doing all he could toward that interest.

The GENERAL SECRETARY announced that the STANDING COMMITTEE recommended that the invitation to hold the next meeting of the Association at ST. LOUIS, be accepted; also that the Committee recommended the selection of the following named gentlemen as officers of the Association for the ensuing year.

President,—O. C. MARSH, New Haven.
Vice President, Section A,—R. H. THURSTON, Hoboken, N. J.
Vice President, Section B,—A. R. GROTE, Buffalo.
General Secretary,—H. CARRINGTON BOLTON, Hartford.
Secretary, Section A,—FRANCIS E. NIPHER, St. Louis.
Secretary, Section B,— GEORGE LITTLE. Atlanta, Ga.
Treasurer,—WM. S. VAUX, Philadelphia.
Auditing Committee,—HENRY WHEATLAND, of Salem, and SAMUEL H. SCUDDER, of Cambridge.

Prof. SAFFORD was authorized to cast the ballot of the Association for the election of officers for the ensuing year with the above result.

The recommendation of the STANDING COMMITTEE that the next meeting of the Association should be held at ST. LOUIS, Mo., on the third Wednesday in August, 1878, was adopted.

Adjourned to meet in sections.

In the evening the Association met in the Senate Chamber at 7.30 P. M. to listen to Vice President PICKERING's address, which was read by Prof. R. H. THURSTON.

The Sixth Day's Session was held in the Hall of Representatives at 10 A. M.

The GENERAL SECRETARY reported the recommendation of the STANDING COMMITTEE that the resolutions offered with regard to the preservation of "The Yellowstone National Park," be adopted by the Association.

The resolutions were then adopted and the President appointed the following *Committee:* Profs. T. B. COMSTOCK, JOSEPH HENRY, O. C. MARSH, Lieut. G. M. WHEELER, and Major J. W. POWELL.

The GENERAL SECRETARY presented the following resolution, recommended by the STANDING COMMITTEE, for adoption.

Resolved, That a permanent committee of five be appointed, to be entitled a Committee on the Introduction of Studies in Science into the Schools of the Country, said Committee to report to the Association in writing from time to time, such facts relating to this subject, and such method of facilitating the introduction of studies on science into the schools, as they may deem wise.

The resolution was adopted.

The President appointed as such Committee Profs. J. D. RUNKLE, A. R. GROTE, N. S. SHALER, J. W. POWELL and N. T. LUPTON.

The following, also recommended by the STANDING COMMITTEE, was adopted:

Resolved, That a Permanent Committee of five be appointed, to be entitled, a Committee on the Relations of Science to the Industrial Arts. Said Committee may report annually, in writing, such facts in relation to this subject as they may deem proper.

The President appointed as such Committee: Profs. R. H. THURSTON, J. M. SAFFORD, T. C. MENDENHALL, and Messrs. J. T. WILDER and O. CHANUTE.

The following resolutions were also recommended by the STANDING COMMITTEE:

Resolved, That this Association most respectfully asks the attention of Congress and the country, to the great advances in the science of meteorology and in the art of weather prediction, which might be hoped for if the meteorological observations now taken by the Army Signal office, under the direction of the Secretary of War, were made the subject of special research and discussion by scientific experts.

Resolved, further, that a committee of five members or fellows be appointed by the President to represent this Association before Congress, as petitioners for such permanent and liberal organization of the meteorological service, that the valuable material collected by it may be utilized in the manner here suggested.

Upon motion, these resolutions were adopted, and the PRESIDENT appointed as such Committee, Dr. J. D. PLUNKET, Prof. ELIAS LOOMIS, Prof. N. S. SHALER, Prof. G. HINRICHS, Col. J. B. KILLEBREW.

The following resolution was also adopted on recommendation of the STANDING COMMITTEE.

Resolved, that a Committee of Finance, of which the Treasurer and Permanent Secretary shall be members, be appointed, for the purpose of obtaining permanent funds for the Association, and of advising with the Treasurer and Secretary in relation to financial matters.

The GENERAL SECRETARY announced the presentation to the Association of a monographical volume containing matters relating to the city of Nashville.

Dr. Lindsley said that Samuel Watkins, President of the Nashville Gaslight Company, and President of the Board of Education, together with the Local Committee, would distribute four hundred copies of the volume to officers and members of the Association. The contents of the volume were as follows: Second Annual Report of the Board of Health, gotten out with special reference to this Association. Report on the topography of Nashville, by Maj. Wilbur F. Foster, illustrated with a map embracing an area of three miles. Report on the geology of Nashville, by Prof. Safford, State Geologist. Report on our water supply, with a careful analysis, by Prof. Lupton. Report upon the climate of Nashville, by Dr. A. C. Ford, of the Signal Service. Interesting facts in Nashville's history, taken from the newspapers and other sources, by Anson Nelson, Secretary of the Tennessee Historical Society. Report by the Health Officer upon the sanitary condition of Nashville. A complete index, by Dr. George Blackie. Dr. Lindsley said it was intended as a memorial volume.

Prof. COPE moved that the thanks of the Association be tendered for these volumes, which was unanimously carried.

Prof. T. STERRY HUNT, from the Committee on the International Congress of Geologists, presented a report of the Committee.

[This report is printed in full in the first part of this volume.]

The report was accepted, and the following recommendation of the STANDING COMMITTEE was adopted:

That in addition to the names of Prof. J. P. LESLEY, of Philadelphia, and Prof. A. C. RAMSEY, director of the Geological Survey of Great Britain, already added to the International Committee, the Presidents, for the time being, of the Geological Societies of FRANCE, LONDON, EDINBURGH, DUBLIN, BERLIN, BELGIUM, ITALY, SPAIN, PORTUGAL, and of the Imperial Geological Institute of Vienna be invited to form part of our commission.

Four persons, on recommendation of the STANDING COMMITTEE, were elected as members.

Adjourned to meet in Sections.

In the evening the Association met in the Hall of Representatives at 7.30 P. M.

The following resolutions were read by the GENERAL SECRETARY, and adopted by the Association:

Resolved, that the thanks of the Association be extended to the TENNESSEE HISTORICAL SOCIETY for the kind and hospitable manner in which they have received the members of our body, and for the magnificent social entertainment, so splendidly illustrating the hospitality and beauty of Tennessee.

Seconded by Prof. J. LAWRENCE SMITH.

Resolved, That we express to the trustees and professors of the VANDERBILT UNIVERSITY, our heartfelt thanks for their reception of the members of this Association at their noble institution, which is a glorious memorial of the generosity of a man impelled by the silent and powerful influence of a true and noble wife.

Seconded by Prof. O. C. MARSH.

Resolved, That we express our thanks to the members of the YOUNG MEN'S CHRISTIAN ASSOCIATION for the kind and generous courtesies extended to us, and that we express an appreciation of their high mission and their efforts to elevate and ennoble their fellow men.

Seconded by Prof. A. R. GROTE.

Resolved, That we express our feelings of gratitude to the PRESS for the manner in which their columns have been opened to the publishing of our proceedings in detail.

Seconded by Maj. J. W. POWELL.

Resolved, That our thanks be returned to the FISK UNIVERSITY for

their kind invitation to visit their institution, which we were prevented from accepting by the pressure of our business, and by the numerous previous engagements we had made, and that we recognize their institution as destined one day to stand side by side with the first in the land, elevating a race that was brought here through the inscrutable will of an overruling Providence, and are now launched forth in a new career with rights as broad as any in the land.

Seconded by Capt. W. H. Dall.

Resolved, That the thanks of the Association are due to various Railway and Steamboat lines for reductions and various facilities offered to the members, and more especially to those roads which have so generously invited the Association to excursions over their lines, notably the railway from this place to Chattanooga, and the Texas Pacific Railroad.

Seconded by Prof. T. Sterry Hunt.

Resolved, That the sincere thanks of the Association be tendered to the Western Union Telegraph Company for the unexpected and generous offer of the use of the lines of their extensive and perfect telegraph system, this being the first time in the history of the Association that this great convenience has been afforded them.

Seconded by Prof. T. C. Mendenhall.

Resolved, That the thanks of the Association be tendered for the several cordial invitations from Cincinnati and St. Paul to hold the next meeting in those cities, and that while unable to accept these invitations for the next meeting, we, the members of the Association, hope that the opportunity will be again given for their consideration.

Seconded by Prof. H. Carrington Bolton.

Resolved, That the thanks of this Association are due, and that they are hereby tendered to the Governor and to the Secretary of State—acting Governor—for the courtesies extended to the Association by them previous to and during the present meeting, and especially for the use of rooms in the Capitol.

Seconded by Perm. Sec'y F. W. Putnam.

Resolved, That the Association acknowledge with thanks the active coöperation and assistance of Messrs. Lindsley, Lupton and Safford of this body, and the others, who, with them, compose the Local Committee of the citizens of Nashville.

Seconded by Prof. E. T. Cox.

Resolved, That this Association desires to express to the Mayor and to the People of Nashville, a full appreciation of the hearty reception, the courtesy and the great hospitality which have been extended to the

Association as a body and to individual members, and the sincere thanks of this body are hereby tendered therefor.

Seconded by Prof. R. H. THURSTON.

After remarks by Acting Governor, Col. C. N. GIBBS, President NEWCOMB said:

The hour of our adjournment has now arrived, but I cannot allow the occasion to pass, without adding some general expression of our feelings to the several resolutions of thanks which have been passed. Without expressing any opinion as to whether business or pleasure should be regarded as the main object of these meetings, no one will deny that we may look back upon the opportunities of extending our acquaintance among the appreciative fellow-citizens of various parts of our country as one of their valuable results. That this result has been reached to an entirely unexpected degree is, I am sure, the sentiment of every member present. We may have been received as sumptuously by more populous communities, but never more heartily, and never have we been more conscious of the appreciation of the objects of the Association by a whole community.

We have met this evening to pay a debt of seventeen years' standing, to the city of Nashville, and I am glad to be able to say that one of the gentlemen, who, in 1860, invited the Association to meet here, is now Secretary of the Local Committee. And now, what shall we say to these citizens who have treated us so kindly? We can only faintly express an appreciation of all they have done for us.

Retiring from this chair I scarcely know how to express my appreciation of the very great kindness with which you have treated me since I have filled it. My total inexperience in presiding, you have, as it were, helped along by expressions of appreciation of my feeble efforts, for which, in retiring to take my place among the small but honored body of your past Presidents, I tender my most hearty thanks.

President Newcomb then declared the Association adjourned to meet at ST. LOUIS on WEDNESDAY, AUGUST 21, 1878.

A. R. GROTE,

General Secretary.

REPORT OF THE PERMANENT SECRETARY MADE TO THE STANDING COMMITTEE AT NASHVILLE.

The following cash account embraces the period from August 4, 1876, to August 11, 1877, including the Buffalo Meeting and closing just prior to that of Nashville. It will be noticed that the receipts were not sufficient to meet the cost of printing the volume of Proceedings and the other expenses of the Association within $753.42, which, added to the outstanding debt of $960.69, leaves the Association in debt to the Permanent Secretary to the amount of $1714.11, at this date. It is, therefore, necessary to urge economy at the present meeting, especially in regard to printing.

The Permanent Secretary has continued to employ, at his expense, an assistant at the office of the Association at Salem, and, as stated in former reports, the numerous details to be attended to render it necessary that the time of one person should be exclusively devoted to the work.

Fifty dollars have been added to the Life Membership Fund during the year and made over to the Treasurer for permanent investment. This fund now stands as follows:—

$232.00 temporarily invested by Permanent Secretary.
25.50 accrued interest to date on above amount.
50.00 invested by Treasurer.

$307.50

The Treasurer reports that the total Fund in his possession, at date, with accrued interest, amounts to $1816.33.

F. W. Putnam,
Permanent Secretary.

Salem, August 11, 1877.

AMERICAN ASSOCIATION FOR

Dr. IN ACCOUNT WITH F. W. PUTNAM,

1876–77.

To Expenses of Buffalo Meeting:—		
General Expenses at Buffalo	$ 175 08	
500 copies Constitution and List of Members	38 75	
Committee on W. M. & C., bill of printing	25 50	
		$ 239 33
Expenses of Buffalo Volume, 1004 *Copies:—*		
Illustrations	26 10	
Composition, Paper and Press-work	1,247 37	
Binding 972 in Paper, 25 in Cloth, 7 in ½ Morocco, and 25 cloth covers	211 87	
Extra Copies, Addresses and Reports of Committees	45 43	
Wrapping 800 for distribution	10 50	
Distribution to members: Mail and Express	95 85	
		1,637 12
General and Office Expenses:—		
Printing Circulars, Blanks, Tickets, etc.	93 00	
Binding and Cloth Covers, for Back Volumes	218 85	
Boxes for storage of Back Volumes of Proceedings	80 66	
Postage, Express and Telegrams	189 83	
Rent of Office to July 1, 1877	100 00	
Fuel	38 00	
Janitor	26 00	
Stationery and Minor Office Expenses	34 87	
		781 21
Life Membership Fund; Paid to Treasurer		50 00
Permanent Secretary, Balance last Account		960 69
Permanent Secretary, Salary for 1876–77		1,000 00
		$4,668 35

SALEM, Aug. 11, 1877.

I have examined the above account and certify that

ADVANCEMENT OF SCIENCE.

PERMANENT SECRETARY.

	Cr. 1876–77.
By Assessments previous to the 25th Meeting	$ 213 00
Assessments for (Buffalo) 25th Meeting	1,545 00
Assessments for (Nashville) 26th Meeting	261 00
Entrance Fees, 25th Meeting	595 00
Entrance Fee, 26th Meeting	5 00
Fellowship Fees	18 00
Publications sold, and Binding	260 64
Donation from a Member	6 00
Express charge refunded	1 00
Life Membership Commutation	50 00
Balance due Permanent Secretary	1,714 11
	$4,668 35

the same is correctly cast and properly vouched.

HENRY WHEATLAND, *Auditor.*

PUBLICATION ACCOUNT OF THE PERMANENT SECRETARY.

Since the account printed in the Buffalo volume, and dated May 1, 1877, 1004 copies of the Buffalo volume have been received from the printer, and the following volumes have been distributed: — To members, 702 copies of the Buffalo volume and 48 of other volumes; by vote of the Standing Committee, 151 Buffalo, and 86 other volumes; 13 Buffalo, and 286 other volumes have been sold.

Of the Memoirs, 3 copies have been sold and one has been sent out by vote of the Standing Committee.

F. W. Putnam,
Permanent Secretary.

Salem, July 19, 1878.

INDEX.

Page.

Act of incorporation xvi
Address of O. C. Marsh, Vice President, Section B 211
——— ———E. C. Pickering, Vice President, Section A 63
——— ———Daniel Wilson, Chairman Subsection of Anthropology 319
Agamic Reproduction among the Cynipidæ 302
American Association of Geologists and Naturalists, Meetings and Officers of.. xiii
Antimony Ores from Sevier County, Ark 181
Androscoggin River, Maine, Geology of the Region about the Head-waters of.. 277
Amia, Respiration of 306
Astronomical Telescopes, New Quadruple Objectives for 127

Barber, E. A., Habits of the Moqui Tribe 310
Barium, Strontium and Calcium 188
Barnard, J. G., Alleged Error in Laplace's Theory of the Tides 73
Bassett, H. F., Agamic Reproduction among the Cynipidæ 302
Bowers, Miss Virginia K., Title of Paper read 315
Bross, Wm., Title of Paper read 316

Calcium, Barium and Strontium 188
Campbell, A. C., Title of Paper read 178
Cash Account of Permanent Secretary 394
Cincinnati, Ohio, Invitations from 380
Classification of the Extinct Fishes of the Lower Types 292
Committee Local, for St. Louis Meeting xii
——————— of Nashville Meeting viii
——————— on International Geological Congress, Report of I
——————— on Zoölogical Nomenclature, Report of 7
Committees, Special ix
Communications, Titles of 178, 202, 207, 315, 366
Constitution xvi
Cope, E. D., Classification of the Extinct Fishes of the Lower Types 292
——— ——— Titles of papers read 316
Cox, E. T., Title of paper read 316
Cranium in Ancient Mounds in Michigan, Artificial Perforation of 335
Cynipidæ, Agamic Reproduction among 302

Deceased Members lii
Drake, E. L., Title of paper read 316
Dunnington, F. P., Action of dilute acid upon Ferrous Sulphide made from cast-iron 185
Dunnington, F. P., Antimony Ores from Sevier County, Ark 181

Elliott, Arthur H., Title of paper read 202
Elliott, E. B., Titles of papers read 178

Fellows xli
Ferrous Sulphide made from cast-iron, action of dilute acid upon 185
Fishes, Extinct Classification of the Lower types 292
Forshey, C. G., Physics of the Gulf of Mexico and the Mississippi River 134
——————— — — Physics of the Lower Mississippi River 148

General Secretary, Report of 373
Gillman, Henry, Artificial Perforation of the Cranium in Ancient Mounds in Michigan 335
Goniometer, Reflecting, Improvement in use of 123
Grote, Aug. R., New Specimens from the Water-lime Group at Buffalo, N. Y. 300
——— ——— On International Scientific Service 57
——— ——— Report of General Secretary 373
——— ——— Title of paper read 316
Gulf of Mexico and the Mississippi River, Physics of 134
Gundlach, Ernst, New Quadruple Objective for Astronomical Telescopes 127
——— ——— Title of paper read 297

Hall, James, Hudson River Group in American Geological Nomenclature 259
Hedrick, Benj. S., Titles of papers read 202, 316
Holden, E. S., Proper Motion of the Trifid Nebula 120
Hudson River Group, History and value of the Term, in American Geological Nomenclature 259
Hunt, T. Sterry, Older Rocks of Western North America 265
——— — ——— Report of Committee Geological Congress 1
Huntington, J. H., Geology of the Region about the Head-waters of the Androscoggin River, Maine 277

Indians, The former and present number of 340
Indium, Spectrum of 125
Ingram, Mrs. H. K., Title of paper read 315
International Scientific Service 57
Invitations for 1878 379
Iron, Steel and other metals, Test of 98
Isawa, Shuje, Title of paper read 366

Jeffrey, M., Title of paper read 178
Julien, Alexis A., Titles of papers read 207, 366

Kercheval, Thomas A., Address of Welcome by 374
Killebrew, J. B., Geology and Topography of the Oil Region of Tennessee 266
Kirkpatrick, R. L., Title of paper read 315

Laplace's Theory of the Tides, Alleged error in 73
Lea, John M., Address of Welcome by 375
Life Members xxvi
Local Committee for St. Louis Meeting xii
——— ——— of Nashville Meeting viii

Maine, Geology of the Region about the Head-waters of the Androscoggin River 277
Mallery, Garrick, The former and present number of our Indians 340
Marsh, O. C., Address of 211
Meehan, Thomas, Title of paper read 315
Mees, C. Leo, Titles of papers read 202, 207
Meetings and Officers of the Association xv
——— ——— ——— ——— of Geologists and Naturalists xiv
Members xxvi
——— elected at Nashville 1
Mendenhall, T. C., Title of paper read 178
——— ——— ——— Wave length of the Blue line of the Spectrum of Indium 125
Metals, Test of 98
Mississippi River, Physics of 134, 118
Missouri River, Annual deposit of, during the Post-pleiocene 287
Moqui Tribe, Habits of the 340

Morehouse, George W., Title of paper read 207
Mounds, Ancient, in Michigan, Artificial Perforation of 335

Nashville Meeting. Executive Proceedings of 367
——— ——— History of 367
——— ——— Invitations at 378
——— ——— Local Committee of viii
——— ——— Members elected at I
——— ——— Officers of vi
Newcomb, Simon, Speeches by 374, 377

Officers and Meetings of the Association xiv
——— — ——— — — — Geologists and Naturalists xiii
——— for St. Louis Meeting xi
——— of Nashville Meeting vi
——— Sections, Nashville Meeting vii
Oil Region of Tennessee. Geology and Topography of 266
Order of Proceedings in Organizing a meeting xxv
Osborne, J. W., Wind-vane Rotations 174

Patron xxvi
Permanent Secretary. Cash Account of 394
——— ——— Report of 393
——— ——— Publication Account of 396
Pickering, E. C., Address of 63
Pitt, W. H., New Specimens from the Water-lime Group at Buffalo, N. Y. 300
Post-pleiocene. Annual deposit of Missouri River, during the 287
Powell, J. W., Titles of papers read 315, 366
Putnam, F. W., History of Nashville Meeting 367
——— —— Report, as Permanent Secretary 393

Report of General Secretary 373
Reports of Committees ..... I, 387
Resolutions passed at the Nashville Meeting 385, 386
Respiration of Amia 305
Ridley, James A., Title of paper read 316
Rocks, Older, of Western North America 275
Rogers, William B., Letter from 373
Rust, Horatio N., Title of paper read 366

Safford, James M., Titles of papers read 316
Schweitzer, Paul, Barium, Strontium and Calcium 188
——— —— Title of paper read 202
Shaler, N. S., Titles of papers read 315, 316
Smith, J. Lawrence, Titles of papers read 178, 202
Spectrum of Indium 125
Springer, Alfred, Title of paper read 202
Steam Engine, On a New Type of 85
Steel, Iron and other Metals, Test of 98
St. Louis Meeting. Local Committee for xii
——— —— Officers for xi
——— Mo., Invitations from 379
St. Paul, Minn., Invitation from 382
Strontium, Barium and Calcium 188
Summers, T. O., jr., Titles of papers read 207, 366

Tennessee, Geology and Topography of the Oil Region of..... 266
Thurston, R. H., New Method of Planning Researches..... 114
——————— — On a New Type of Steam Engine..... 85
——————— — — Test of Iron, Steel and other Metals..... 98
Titles of Communications.....178, 202, 207, 315, 366
Todd, J. E., Annual Deposit of the Missouri River during the Post-pleiocene.. 287
Trifid Nebula, Proper Motion of..... 120

Vice President Marsh, Address of..... 211
—— ——— Pickering, Address of..... 63

Wallace, Samuel J., Title of paper read..... 315
Ward, R. H., Modification of Wenham's Reflex Illuminator..... 205
——————— — Title of paper read..... 207
Water-lime Group at Buffalo, N. Y., New specimens from..... 300
Wenham's Reflex Illuminator..... 205
Wetherby, A. G., Title of paper read..... 316
Wilder, B. G., Respiration of Amia..... 306
Wiley, Harvey W., Improvement in use of Reflecting Goniometer..... 123
Wilson, Daniel, Address of..... 319
Wind-vane Rotations..... 174

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